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SOIL INVESTIGATION AND HUMAN HEALTH RISK ASSESSMENT FOR THE RODNEY STREET COMMUNITY: PORT COLBORNE (2001)

STANDARDS DEVELOPMENT BRANCH
REPORT NO. SDB-010-3511-2001

MARCH 2001

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Ministry
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SUMMARY
Soil Investigation and Human Health Risk Assessment Report for the Rodney Street Neighbourhood, Port Colborne, March 2001

Conclusions

The Soil Investigation and Human Health Risk Assessment Report for the Rodney Street community has determined that elevated nickel and lead soil contamination on some properties warrants further action. The recommendations for further action follows completion of a comprehensive soil investigation and human health risk assessment that examined over 1,300 soil samples to determine the safety of metal levels at 179 properties in the Rodney Street neighbourhood. The health risk assessment reviewed concentrations of eight metals found in surface soils and has recommended that an intervention level of 10,000 parts per million (ppm) also referred to as µg/g (micrograms per gram or one millionth of a gram) be set for nickel and an intervention level of 1,000 ppm be set for lead. No further action for the remaining six metals (arsenic, antimony, beryllium, cadmium, copper or cobalt) is required.

In carrying out the investigation and assessment, the Ministry of the Environment identified nickel levels in excess of 10,000 ppm at 16 of 179 properties. As a result of historical emissions from INCO, these nearby properties were found to have nickel soil concentrations in the upper 30 cm of soil. The ministry also found lead levels in excess of 1,000 ppm at 10 of the 179 properties, including two that had already been identified as having elevated nickel levels. Similar lead levels are known to be found in older, established urban neighbourhoods resulting from the historical use of lead based paints, leaded gasoline and discarded lead-acid batteries.

The study's key findings for the Rodney Street Community, include:

1. 16 of 179 properties have elevated nickel levels in excess of 10,000 ppm;
2. 10 of 179 properties have elevated lead levels, in excess of 1,000 ppm, including two that were previously identified as having high nickel concentrations;
3. A total of 24 properties warrant further action;
4. Stringent nickel cleanup levels, specific to the Rodney Street neighbourhood, have been developed based on exposure for young children;
5. Nickel levels in the neighbourhood do not pose any immediate or long term risks to adults;

6. No further action is warranted for the remaining six metals (Arsenic, Antimony, Beryllium, Cadmium, Copper and Cobalt).

Introduction

INCO operated a base metal refinery from 1918 to 1984 in the City of Port Colborne. Emissions from this facility have resulted in soils covering a wide area northeast of this facility having concentrations of nickel, copper and cobalt above the ministry's soil remediation criteria. The remediation criteria are based on potential impact to sensitive plant species. INCO is undertaking a Community Based Risk Assessment (CBRA) to address the remediation of this area. A Public

area. A Public Liaison Committee has been formed for ongoing public consultation on the proposed Community Based Risk Assessment, and on November 30, 2000, endorsed the Scope of Work for the CBRA.

Previously, the Ministry of the Environment and the Regional Niagara Public Health Department, conducted a health risk assessment in 1997, to determine if exposure to elevated nickel, cobalt and copper soil concentrations in Port Colborne may result in the potential for adverse health effects. The report concluded that no adverse health effects are anticipated. Furthermore, the review of population health data did not indicate any adverse health effects which may have resulted from environmental exposures.

Following the release of this 1997 health risk assessment the ministry undertook additional soil sampling studies in 1998 and 1999. These additional studies involved a more extensive soil sampling program and resulted in a better understanding of the extent of soil metal contamination in the Port Colborne area. The 1998 and 1999 soil surveys did not find any more serious soil contamination than in previous surveys therefore, the health risk study conclusions from 1997 are still applicable to the 1998 and 1999 soil investigations.

In September 2000, soil nickel levels from a single Rodney Street property were found to exceed the maximum nickel level used in the 1997 health risk assessment. Subsequently soil from 17 properties, on or in the vicinity of Rodney Street, was collected and analyzed for 20 metals and metalloid elements. Preliminary results in October 2000 indicated that surface soil nickel levels ranged up to 17,000 ppm, and that the soil metal levels were extremely variable between properties. In November 2000, the ministry sampled soil from the residential properties south of Louis Street to the lake, and east of the Welland Canal to INCO, to determine the extent of this contamination. Sampling results for these 179 properties, in what has become known as the Rodney Street neighbourhood, follow below.

In addition to the extensive soil survey the ministry undertook a new health risk assessment. The results of the soil survey and health risk assessment have been provided to the Rodney Street neighbourhood homeowners and the Regional Niagara Public Health Department, and will be considered in the proposed Health Study for the Rodney Street community, announced December 11, 2000.

Soil Investigation Results

Soil nickel levels varied substantially between properties. The maximum soil nickel level found was 17,000 ppm while the average was 2,545 ppm. Sixteen properties exceeded the maximum value used in the 1997 human health risk assessment (9,750 ppm) and all but one property had soil nickel levels that exceeded the MOE generic effects-based soil guideline (200 ppm) which is based on potential impact on sensitive plant species which are used because they show adverse effects at lower concentrations than other organisms.

Other metals levels above ministry guidelines (lead, cobalt, copper, beryllium, arsenic, zinc, antimony, selenium) were found on some or all of the properties, and are also presented in the

ministry report. Soil metal concentrations tended to increase with depth to a maximum at between 10 cm to 20 cm, and based on limited digging, are unlikely to be found deeper than 30 cm on most properties.

Nickel, copper, cobalt, and arsenic soil contamination in the Rodney Street Community is unquestionably related to INCO, and selenium and zinc soil contamination is likely INCO related. The source of the nickel, copper, cobalt, arsenic, selenium, and zinc soil contamination across the Rodney Street neighbourhood is believed to be fugitive emissions (i.e. emissions from vents, windows, doors) from INCO that occurred early in the refinery's history, possibly before the construction of the stack in 1929. The highest nickel, copper, cobalt, and arsenic soil concentrations occurred on properties along the southeast end of the neighbourhood on Rodney, Mitchell, and Davis Streets.

The randomly scattered lead contamination observed in the Rodney Street neighbourhood is related to domestic residential lead sources and not to INCO emissions. Lead-contaminated properties often had elevated concentrations of cadmium, chromium, barium, zinc, copper, and antimony. Lead and antimony soil contamination is an indication that batteries may have been stored or disposed of on the property, whereas lead in conjunction with barium, cadmium, chromium, copper, and zinc is an indication of soil contaminated by exterior lead-based paint.

With the exception of one property where elevated beryllium levels occurred with high lead and other heavy metal levels, the marginally higher beryllium soil concentrations across the Rodney Street neighbourhood are a combination of naturally higher levels in local shale formations and extensive historical use of slag in local road construction.

The "patchwork" pattern of high and low soil contaminant concentrations on residential properties in the Rodney Street neighbourhood is related to property maintenance and landscaping. It also indicates that the source of the soil contamination is largely historic, probably before the stack was erected, or at least that recent deposition was substantially lower, as more recently landscaped properties have not become re-contaminated to the levels found on undisturbed properties.

The "solubility" of the soil contaminants found in the Rodney Street neighbourhood is very low, ranging from less than 1 per cent for most metals to 3.8 per cent for lead. This means the metals are relatively immobile in the soil and do not readily react with the environment, which accounts for the remarkably minor amount of nickel damage observed on sensitive plant species and why there is no consistent relationship between nickel in vegetable produce and soil nickel levels in residential vegetable gardens.

Human Health Risk Assessment

A human health risk assessment of the elevated concentrations of eight metals (antimony, arsenic, beryllium, cadmium, cobalt, copper, lead and nickel) found in the surface soils (0-30 cm) of the Rodney Street neighbourhood was also conducted by the ministry. The health risk assessment for nickel was peer reviewed by an international panel of experts. Peer reviewer

agencies included:

- Toxicological Excellence for Risk Assessment (*TERA*), Cincinnati, Ohio;
- Agency for Toxic Substances and Disease Registry (ATSDR), Atlanta, Georgia;
- United States - Environmental Protection Agency (US-EPA), Washington, D.C.; and
- Norwegian National Institute of Occupational Health, Oslo, Norway.

A human health risk assessment is conducted when chemical contaminants are found at levels that raise concerns about potential risk in the community. The multimedia approach to health risk assessment examines total exposure to contaminants through a number of possible pathways, such as air, soil, drinking water and food.

While this study is health-based, it is not a community health study. This health-based risk assessment is directed at assessing exposure to selected metals in Rodney Street neighbourhood properties. The assessment evaluated whether health-based exposure limits are exceeded and whether any exposure level (or soil concentration) warrants further actions (including soil remediation) to reduce exposure. The results of the health risk assessment have been provided to Regional Niagara Public Health Department and will be considered in the Health Study for the Rodney Street community, that was announced December 11, 2000.

Nickel

The plausible "worst case" exposure model indicates that when the Rodney Street community nickel exposure from all sources is averaged over a lifetime, the resulting chronic daily intake (CDI) estimate is about 8 µg/kg/day or 40 per cent of the United States Environmental Protection Agency's reference dose (R*f*D) of 20 µg/kg/day. However, when exposure is broken down by age group, the highest exposures are for the infant and toddler age groups (up to 5 years old). Worst case exposures for this age group exceed the U.S. EPA reference dose. The major contributor to daily intakes of nickel is supermarket food found in Canada as determined by Health Canada which is independent of any local nickel exposures in the Rodney Street community.

The "reference dose" is defined as the level below which lifetime average exposures would not be expected to result in adverse human health effects. This means that short term exposures to levels above the reference dose would not be expected to result in adverse health effects, provided that the exposures are not high enough to cause acute effects and provided that the dose experienced over a life-time did not exceed the reference dose. It should be further noted that an exceedance of the reference dose does not mean that adverse health effects will occur. However, the potential of adverse effects occurring increases as the life-time average daily dose rises above the reference dose.

As a result, a stringent site-specific soil intervention level of 10,000 ppm of nickel for soil was developed specific for the Rodney Street neighbourhood based on ensuring toddler exposure was below the U.S. EPA reference dose.

Three independent sets of analyses of Port Colborne soils, carried out by the Ontario Ministry of

Mines and Northern Development, INCO and Jacques Whitford Environmental Limited, have shown that nickel oxide is the predominant form of nickel present in Port Colborne soil. Minor amounts of elemental nickel and nickel-copper alloys were also reported. Nickel sulphate and nickel sulfide were not found to be present.

Lead

Lead in soil has long been recognized as posing potential risk, particularly to younger children up to 5 years of age, who may play in backyards and parks. Therefore, young children were considered the most sensitive to exposures for direct soil/dust ingestion.

Reported lead levels for the Rodney Street community were compared with other neighbourhoods in Ontario where community blood lead studies were undertaken. Average soil lead levels in the Rodney Street community (mean of 204 ppm in surface samples) are essentially no greater than, and in many cases less than, those expected for other urban residential sites in Ontario. As a result, estimated exposures (and hence blood lead levels) are predicted to be similar to those for other urban Ontario populations.

It is prudent, however, to conclude that in the 10 residences with reported soil lead levels higher than 1000 ppm there may be some possibility for exposures and higher blood lead levels in children who routinely play in these areas.

As a result, the report recommends an intervention level be established for this community at a soil lead level of 400 ppm for children play areas **with bare soil** on residential properties or in public areas, and at a level of 1000 ppm for all other areas of these properties **covered by sod or grass** to which children have access. Residents at properties exceeding 1000 ppm lead in soil should be advised to avoid contact and to not consume vegetables from backyard gardens. Additional ways to reduce exposure to the lead in soil are presented in the ministry's fact sheet, *"Frequently Asked Questions About Lead Contamination"*.

The Regional Niagara Public Health Department also has information on how to reduce exposure to lead in soil. The Medical Officer of Health is providing blood lead screening tests to anyone living or frequently spending time in the area and strongly recommending that pregnant women, of reproductive age, pregnant women and children under seven, participate in the blood lead level screening tests by calling the heavy metal health hotline at 1-905-688-1068.

Arsenic

People everywhere in North America are exposed to low levels of arsenic in the environment and as such everyone has a certain amount of risk. Exposures can occur by a number of different pathways including normal diet and drinking water. The measured soil arsenic levels in the Rodney Street neighbourhood were compared to the levels found in other communities in Ontario with elevated levels of soil arsenic. In the case of these other two communities, no adverse health effects were predicted to be associated with the arsenic in the soil.

It is concluded that the measured levels of arsenic in the Rodney Street community soils do not pose an undue health risk to residents of this community based on consideration of: the very low measured availability of the arsenic in these soils; comparison to typical levels elsewhere; and knowledge of health study outcomes involving arsenic soil exposure in other Ontario communities.

Antimony, Beryllium, Cadmium, Cobalt and Copper

Taking the same approach as used for nickel, plausible worst case exposure estimates were modeled using the maximum reported levels of each metal in the Rodney Street neighbourhood surface soil, Port Colborne municipal drinking water, ambient air, supermarket food and Rodney Street neighbourhood backyard produce.

For the metals antimony, beryllium, cadmium, cobalt and copper, estimated total daily intakes for all age groups were well below stringent oral or breathing exposure limits from major recognized jurisdictions, such as, the U.S. EPA, World Health Organization and Health Canada. No adverse health effects are anticipated to result from exposure to antimony, beryllium, cadmium, copper or cobalt, in soils in the Rodney Street community.

Therefore, soil intervention levels were not developed for these metals for the Rodney Street community.

Study Participants

The Rodney Street Community study involved many scientists and technicians from the Ministry of the Environment. The following staff of the Standards Development Branch Ecological Standards and Toxicology Section (Phytotoxicology) participated in sample collection and sample processing: Marius Marsh, Murray Dixon, Bill Gizyn, Bob Emerson, Ron Hall, Danuta Roszak, Deborah Terry, Melanie Appleton, Richard Chong-Kit, Mike Mueller, and Al Kuja. Randall Jones co-ordinated the geo-referencing of the soil samples and the soil data base, and prepared the contaminant contour maps. Al Kuja and Dave McLaughlin were the principal authors of Part A of this report.

The Human Health Risk Assessment was conducted by toxicologists of the Human Toxicology and Air Standards Section. Brendan Birmingham co-ordinated this effort and is the principal author of Part B of this report. Contributing toxicologists included Scott Fleming, Satish Deshpande, Marko Pagliarulo, and Audrey Wagenaar. Bryan Leece of Dillon Consulting Ltd. provided technical assistance.

Laboratory Services Branch personnel provided critical laboratory support. Liz Pastorek administered the contract for the private laboratory that conducted the soil analysis. Tender evaluation was conducted by Peter Drouin. The initial quality control check was handled by Sathi Seliah. Rusty Moody and Jim Howden provided data monitoring and data management duties. The in-house laboratory analysis required to ensure data quality was conducted by Lian Liu and Julie Uzonyi (ICP - metals) and Hung Sing Chiu and Regina Pearce (hydrides).

Jacques Whitford Environmental Limited providing vegetable produce and garden soil data for the Rodney St. community and Port Colborne in general, and air monitoring data for selected schools.

Paul Nieweglowski and Bob Slattery of the Niagara District Office provided liaison between the Ministry's Operations Division and the Environmental Science and Standards Division. Rick Day was the communications officer.

Peer reviewers of the Part B Human Health Risk Assessment for nickel were:
- Dr. John Wheeler, Agency for Toxic Substances and Disease Registry (ATSDR), Atlanta, Georgia,
- Ms. Ambika Bathija, U.S. EPA, Washington, D.C.,
- Dr. Lynne Haber, Toxicological Excellence for Risk Assessment (*TERA*), Cincinnati, Ohio,
- Dr. Tor Norseth, Norwegian National Institute of Occupational Health, Oslo, Norway.

Laura Morra of the Ecological Standards and Toxicology Section and Tony Ho of the Drinking Water, Wastewater, and Watershed Standards Section provided internal document review.

Overall project management was provided by George Crawford, Dale Henry, Dave McLaughlin, and Paul Niewegloski.

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Soil Investigation and Human Health Risk Assessment for the Rodney Street Community: Port Colborne (2001)
Part A: Soil Investigation

BACKGROUND

From 1918 to 1984, the International Nickel Company Limited (INCO) operated a base metal refinery in the city of Port Colborne. Between the years 1972 and 1999, the Ontario Ministry of the Environment (MOE) conducted numerous investigations to document the impact of INCO's emissions on soil and vegetation in and around Port Colborne. These investigations concluded that 65 years of nickel refining has resulted in extensive heavy metal soil contamination in the Port Colborne area. Nickel, copper, and cobalt concentrations in surface soil exceed the MOE Table A effects-based generic soil remediation criteria (see *Guideline for Use at Contaminated Sites in Ontario*, Appendix D, reference 6) in residential communities adjacent to INCO and for considerable distances downwind (northeasterly). In addition to these three heavy metals, soil arsenic, selenium, and zinc concentrations are also elevated at some sample sites. However, unlike nickel, copper, and cobalt concentrations that are consistently and substantially elevated over a large area, the soil arsenic, zinc, and selenium levels exceed normal Ontario background ranges only in a few areas close to INCO.

Extensive sampling and modelling conducted by the MOE in the city of Pt. Colborne and the surrounding area in 1998 and 1999 demonstrated that soil nickel concentrations exceed the MOE Table F soil background-based guideline up to 28 km downwind of the refinery, covering a 345 km^2 area of the Niagara peninsula [1, 2]. Furthermore, the MOE Table A effects-based soil nickel guideline is exceeded for a distance of up to 3 km downwind of INCO over an area of almost 29 km^2. In addition, copper and cobalt also exceed their corresponding effects-based Table A soil guidelines in smaller areas of the community, mainly immediately east and northeast of the refinery. The MOE guideline criteria for nickel, copper, and cobalt are all based on phytotoxicity (injury to vegetation). Numerous MOE studies conducted on Port Colborne farms in the 1970s and 1980s documented toxicity to agricultural crops as a result of heavy metal soil contamination [7,8,9]. A human health risk assessment conducted by the MOE in 1997 and reviewed by the Regional Niagara Public Health Department concluded that *based on a multi-media assessment of potential risks, no adverse health effects are anticipated to result from exposure to nickel, copper, or cobalt, in soils in the Port Colborne area* [3]. The highest soil nickel level used in that health risk assessment was 9,750 µg/g (dry wt).

The Rodney St. community is located due west of INCO. Like other residential neighbourhoods in Port Colborne, the Rodney St. community has been directly impacted by INCO stack emissions. Also, because of it's close proximity to the refinery, the Rodney St. community was also likely subjected to extensive fugitive emissions, which would have been particularly significant early in INCO's history and prior to the construction of the stack in 1929. Fugitive emissions are process emissions that "leak" out of windows, doors, vents, or other openings. Fugitive emissions tend to impact areas very close to the manufacturing site, whereas emissions

from a stack can have an impact over a much greater area and at much further distances. Previous MOE surface soil sampling in the vicinity of the Rodney St. community to the west and northwest of INCO found that soil nickel concentrations in the general area averaged less than 5,000 µg/g. However, very few surface soil samples were collected and little depth sampling (greater than 5 cm) was done in this part of Port Colborne (the highest soil Ni concentration at 5-10 cm was 2,750 µg/g). No properties on Rodney St. itself were sampled.

During a public information forum held in January 2000 at the Pt. Colborne city hall, a resident of Rodney St. requested that the MOE sample soil on his property. MOE Phytotoxicology scientists sampled the front and back yards of the property in June 2000. Analysis of the soil samples revealed that soil nickel concentrations at depth (10-15 cm) were very high (16,000 µg/g). In addition, soil copper, cobalt, arsenic, lead, and zinc concentrations at depth also exceeded their respective MOE Table A guideline criteria. MOE human health toxicologists conducted a screening level risk assessment on the soil data and determined that the health-based nickel reference dose was exceeded for the maximum nickel concentration found in the front yard of this Rodney St. property. The reference dose calculations incorporate considerable safety factors, and although an exceedence of the nickel reference dose does not automatically mean that an adverse health effect will occur, it does erode the confidence that an adverse effect will not occur, and therefore further investigation is warranted.

As a result of the findings for the single Rodney St. property, the Medical Officer of Health requested that the soil be sampled on the remaining residential properties on Rodney St. This additional sampling of front and back yards was completed on October 3rd and 4th, 2000. A preliminary analysis of the results showed a wide variance in soil nickel concentrations from one property to the next. On some properties the nickel concentrations were highest in the surface soil and lower at depth, on other properties the reverse was observed. Properties with higher soil metal levels were sometimes adjacent to properties with much lower metal concentrations. Soil nickel concentrations tended to be much higher in the front yards of Rodney St. properties than the back yards. In addition to unexpectedly high nickel, copper, and cobalt levels, the soil zinc, arsenic, and lead concentrations were also elevated and were inconsistent with levels observed elsewhere in the Port Colborne area from the previous MOE soil investigations. While collecting soil from the Rodney St. properties it was observed that some yards had considerable non-soil material, such as concrete rubble, cinders, slag, ash, and metal pieces. This suggested that some areas of what is now Rodney St. may have received fill, possibly residential refuse or industrial process waste.

The sources of the soil metal contamination found on some Rodney St. properties could be both stack and fugitive emissions from the INCO refinery, or historic emissions and/or disposal of process waste from INCO or other local industries. In addition, it could be related to contaminated backfill from sewer or water line construction, or from an oil pipeline that was constructed in 1957 and runs from the Welland canal, along the centre of Rodney St., up Davis St., and into INCO [Dave Reed, personal communication]. The long time use of leaded gasoline, improper disposal of batteries, and the weathering or removal of lead-based paint from exterior walls of residential dwellings may have contributed to the elevated soil lead concentrations.

The extent of the unexpectedly high soil metal levels was anticipated to be quite limited if the source was contaminated fill, and could be more extensive if fugitive or stack emissions were the source. In addition, the variability of the soil metal levels between properties made it difficult to judge the extent of the contamination. Therefore, in order to determine with certainty if the elevated soil metal concentrations are due to contaminated fill and limited only to Rodney St., 179 residential properties in the neighbourhood immediately west of the INCO refinery were sampled by MOE scientists and technicians from November 8th to 17th, 2000. The properties in this neighbourhood have been referred to in the extensive local media coverage, and will be referred to in this report, as "the Rodney St. community". In addition to the residential sampling, soil trenches were dug at several locations in the vicinity of Rodney St. to determine if soil at depth was contaminated. Also, the city of Port Colborne requested that the MOE sample fill material that was used in the construction of a playground located on Welland St. north of Nickel St., and therefore trenches were dug in this park.

METHODS

Soil Sampling Strategy

In response to the request of the Medical Officer of Health, on October 3rd and 4th, 2000, MOE Phytotoxicology scientists sampled the front and back yards of the remaining 16 residential properties on Rodney St., and the baseball diamond at the southeast corner of Davis St. and Rodney St. Soil was sampled in duplicate at three sampling depths (0-5cm, 5-10 cm, and 10-15 cm) and placed in labelled polyethylene bags. Standard MOE sampling protocols were followed [4]. Tomato and pepper fruits, as well as surface soil (0-5 cm depth), were collected from a vegetable garden located in the backyard of one of the Rodney St. properties.

As a result of unexpectedly elevated soil metal levels from these 17 Rodney St. properties, the decision was made to sample soil in the front and back yards of the 179 properties situated in the ten block area located north of Rodney St. The sampling area consisted of all residential properties on the south side of Louis St. south to the lake and from Welland St. east to INCO, including; Rodney St., Welland St., Davis St., Fares St., Mitchell St., Kinnear St., Nickel St., Decew St., and the south side of Louis St. This neighbourhood has become known as the Rodney St. community. The sampling was conducted from November 8th to 17th, 2000.

At each of the 179 properties, a soil corer was utilized to collect soil samples from three depth intervals (0-5 cm, 5-10 cm, and 10-20 cm) from the front and back yards. Approximately ten to twelve cores were taken per soil depth increment while walking a grid pattern across the designated sampling area in each yard. Soil cores were placed in labelled polyethylene bags. All yards on all properties in the Rodney St. community were sampled, unless conditions made it impossible to collect a sample. For example, sampling to the 20 cm depth was not possible on every property, as occasionally very rocky fill was encountered. Also, some yards were covered with gravel, asphalt, concrete, or debris, which physically prevented the investigators from sampling both front and back yards on every property. In total 25 properties in the Rodney St. community were not sampled. Because of the large number of properties and the multiple

sample depths, on most properties only single samples were collected so that all samples could be analysed in a reasonable time (more than 1,300 samples were collected). Triplicate samples were collected at two properties on each block. This limited replicate sampling was done to provide a measure of sampling variability. All soil samples were collected at least 1 metre away from driveways, building structures, and fences.

Trench Sampling

Several 2 metre long by 0.5 metre wide trenches were dug using a backhoe supplied by the city of Port Colborne. The purpose of the trenches was to obtain soil samples at depth to determine how deep the contamination extended, and to observe the soil profile for signs of fill, refuse, or process waste. Trenches were excavated to a depth at which contact was made with natural clay, which was about 1 metre in all trenches. Duplicate soil samples were removed from the sides of each trench using a trowel at three depths: 30 cm, 60 cm (which were within what appeared to be layers of coarse fill material), and 90-100 cm, which coincided with the top of the natural clay soil. Soil samples were placed in labelled, polyethylene bags.

Seven trenches were excavated from four areas: 1) the baseball diamond, 2) a vacant lot, 3) the shoulder of Rodney St., and 4) a park. Two trenches were excavated in the baseball diamond at the southeast corner of Davis St. and Rodney St. One trench was located on the outfield side of second base, the second trench was dug in the middle of the outfield. Two trenches were excavated in the undeveloped grassy field situated on the south side of Rodney St. between Welland St. and Fares St. One trench was about 10 metres in from the northeast corner, and the second was about 10 metres in from the northwest corner. Two trenches were excavated on the west side of the playground located between Welland St. and Fares St., north of Nickel St. (the parkette is not named). In addition, 0-5 cm, 5-10 cm, and 10-15 cm duplicate soil samples were collected from eight sites along a sod-covered berm running around the north and west perimeter of the basketball court located in the parkette. Finally, a single trench was excavated on the north shoulder of the road, directly in front of the residence at 124 Rodney St.

Soil Sample Analyses
a) Analysis of metals and hydrides

All soil samples were stored in locked vehicles until they were delivered to the Ecological Standards and Toxicology Section laboratory for processing using standard MOE procedures [4]. The samples were air-dried and ground to pass through a 2mm sieve where vegetation and stoney debris were removed, and then ground a second time to pass through a 355 micron sieve. The fine soil fraction was transferred to the MOE Laboratory Services Branch (LSB). Because of the need to have the analyses conducted as quickly as possible, and with respect for competing laboratory workload commitments for other MOE projects and other communities, LSB arranged to have the Rodney St. community soil samples analysed by an accredited private environmental laboratory. LSB imposed a strict quality management regime on the private lab to ensure data

integrity. The soil samples were analysed for the following inorganic metals: aluminum, barium, beryllium, cadmium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, molybdenum, nickel, strontium, vanadium, and zinc. In addition, the hydrides arsenic, antimony, and selenium were also included in the soil analysis.

b) Determination of Soil pH

For the purpose of interpreting the bio-availability of the soil contaminant concentrations, soil pH was determined for a subset of soil samples collected from twenty properties across the ten blocks of the Rodney St. community. Generally, the selected properties were situated near intersections. MOE standard procedures for determining soil pH were followed [10].

c) Simulated Stomach Acid Leach Test

Ten soil samples containing very high nickel concentrations were selected for simulated stomach acid leach tests for estimating bio-availability for use in the human health risk assessment. Because this procedure is not a standard MOE/LSB protocol, it is described in detail. From each soil sample, 20 g of dried, sieved material was added to 400 ml of 0.17N HCl (pH 1.0) and agitated for 24 hours on a rotary extractor. The mixture was then filtered through a 0.45 micron membrane filter and the filtrate was analysed for the aforementioned metals and hydrides using standard LSB analytical protocols. For each sample, 'percentage leached' was then calculated by dividing the metal concentration (µg/g) in the filtrate by the total soil metal concentration (µg/g) and multiplying the ratio by 100.

d) Data Management and Laboratory Quality Control

In order to expedite the analysis of the 1300 plus soil samples collected from the Rodney St. community the MOE retained the services of an accredited private laboratory. The management of the contract lab was carried out by senior scientists and managers of the MOE LSB. The contract with Agat Laboratories was signed only after a thorough review of their proposal and laboratory procedures and a successful analysis of a pre-selected test sample. The MOE analysed the first 100 soil samples from the Rodney St. community. These same 100 samples were then analysed by Agat and the results compared. This initial comparison was done by staff of the MOE LSB Quality Management Unit. The acceptance criterion was 20%, which is similar to the criterion used for in-house quality control duplicate samples. In other words, each of the Agat Laboratory results had to be within 20% of the corresponding MOE results for the same sample. Only after this first quality assurance target was met successfully were the remaining Rodney St community samples sent to Agat.

All sample submissions sent to Agat contained at least four "check" samples which had been previously analysed as part of the original 100 samples. Each submission also contained field

replicate samples which could be used to measure repeatability of the sampling and analytical processes. The acceptance criteria were 20% for the check samples and 50% for the field replicates. The field replicates had a higher acceptance bracket because it was known from previous work in Port Colborne that between-replicate variability increased as the soil contaminant concentration increased. This is a common occurrence for non-homogeneous samples. Data checking was performed by the manager and a senior scientist of the MOE LSB Spectroscopy Section, as well as Phytotoxicology scientists. If the results for the "check" samples and the replicate data were acceptable, then the rest of the data were checked for outliers. Generally, outliers were found to be due to the improper use of dilution factors. Outlier sample results were either re-calculated or Agat was required to repeat the analyses. Once all these criteria were met, the data were released to the principal authors for use in the preparation of this report.

Several sample submissions were repeated because the ratios of certain elements did not match the observed general trend. In almost all cases, repeat analysis by Agat, and in some cases by MOE, confirmed the original result. Repeat analysis was continued until the data either matched the original "check" samples or were confirmed by MOE analysis. The requirement to conduct repeat analysis to insure data quality resulted in a 3 week delay in the scheduled completion of this phase of the program.

RESULTS

Nickel Speciation

In all previous MOE reports pertaining to soil contamination in Port Colborne the metal concentrations have been reported in µg/g dry weight as total contaminant. "Total" refers to all the metal that can be extracted from the soil via the standard MOE LSB hot acid digestion process. This is a standard process used in all analytical labs for soil analysis. The recent MOE soil studies in Port Colborne made no attempt to determine the various metal compounds or metal species in local soil. This can be important for ecological and human health risk assessment because some metal compounds or species are more bioavailable or more toxic than others, and therefore pose a greater potential risk. For example, nickel chloride is much more soluble that nickel oxide. If most of the total nickel were present as nickel chloride then vegetation injury would be more likely to occur and more nickel would be absorbed into vegetable produce grown in nickel-contaminated soil and through the skin or the human gastrointestinal (GI) tract. The relative toxicities of nickel oxide, nickel chloride, and nickel subsulphide are discussed in more detail in the *Part B Human Health Risk Assessment* portion of this report.

Speciation of metals in soil is both a time consuming process because it requires specialized laboratory equipment and specially trained equipment operators/scientists. Because of the need for special equipment and operators the cost per sample can be several thousand dollars. In addition, it cannot confidently be done on soil samples unless the metal content is quite high (usually above 0.5% or 5,000 µg/g). For these reasons metal Speciation is not routinely

conducted in environmental investigations, and was not previously done on Port Colborne soil samples.

Nickel Speciation was conducted on selected soil samples collected from the Rodney St. community independently by both the Ministry of Northern Development and Mines (MNDM) Geoscience Laboratory in Sudbury [11] and by INCO [12]. Jacques Whitford Environmental Ltd. also submitted selected soil samples from across Port Colborne for metal Speciation as part of their sampling to determine Contaminants of Concern for the Community Based Risk Assessment currently underway in Port Colborne [14]. The MNDM report concluded that nickel oxide was detected in the magnetic fraction of each sample, and that no other nickel phase was detected in either the magnetic or non-magnetic fractions of any of the samples. The INCO report had similar conclusions: the only forms of nickel identified in the Rodney St. soil samples were elemental nickel, nickel alloys (e.g., nickel-copper alloy), and nickel oxide, but specifically neither sulfidic nor halide forms of nickel were detected. The Jacques Whitford results concurred with both the MNDM and INCO reports, in that nickel oxide was the only nickel compound detected, with no evidence of either sulphate or sulphide forms. In addition, correspondence in MOE files cites a 1978 INCO report of analyses of Port Colborne refinery dusts [13]. This report provides elemental analysis of dust collected from the Cottrell Precipitator, which captured dust from the Anode Reverb Furnaces during charging, smelting, and on-stream periods of operation, and so should represent stack emissions in the 1970s. The dust was 38.7% nickel, 10.5% lead, 7.6% copper, 7.1% sulphur, 0.66% cobalt, 0.61% iron, 0.38% arsenic, and 0.14% zinc. The main nickel component was nickel oxide, the main lead component was lead sulphate, and "minor phases" (not quantified) of hydrated nickel and copper sulphate were identified. Therefore, most of the nickel in stack emissions in the 1970s was nickel oxide, and three independent laboratories examining soil from the Rodney St. community and elsewhere across town concluded that nickel oxide, elemental nickel, and nickel metal alloys were the only nickel species found in Port Colborne soil in 2000: specifically, nickel chloride and nickel subsulphide were not identified in any samples.

The oxide form is the most common species of metal in soil around point sources of metal pollution. This is because the metals are either oxidized by the industrial processes or oxidized in the soil by sunlight, heat, moisture, and micro-organisms. Over time the more soluble and unstable metal forms are weathered away leaving the more insoluble and more stable metal oxides. Considering the nature of the refining process and the length of time the nickel has been in the soil it wasn't surprising that nickel oxide is the predominant form of nickel in soil in Port Colborne.

Soil Results

Soil analysis results for all 179 residential properties are summarized in Appendix Table A-1. Soil data in this table are summarized by front and back yards for all three sampling depths, and are identified by MOE/Phytotoxicology station number only. The property addresses that correspond to the station numbers are maintained in MOE files. Property owners/occupiers will

be informed of the station number that corresponds to their property when they receive their copy of this report, which will allow them to "decode" the data in Appendix A-1 and determine the contaminant status of their property. Soil results for samples collected from the trenches are summarized in Appendix Table A-2. Soil levels in Appendix A that exceed MOE Table A generic effects-based guidelines are identified by bold type face and are underlined. Soil concentrations that exceed human health risk-based soil intervention levels, where established, are shaded. Soil pH results for the ten selected soil samples containing very high soil nickel concentrations are listed in Appendix Table A-3. Results of the simulated stomach acid leach tests performed on these same ten soil samples are summarized in Appendix A-4. The mean soil pH and mean percent leach values are summarized in Table 1.

In Table 1 it is seen that soil pH is in the neutral range at all three sampling depths. This is consistent with fine-textured mineral soil and common in surface soil in southern Ontario.

The mean percentages of soil metal concentrations leached from the selected soil samples are very low. Specifically, on average only 0.82% of the nickel could be leached out of the soil samples, only 0.96% of the cobalt was leachable, and only 1.9% of the copper could be leached by simulated stomach acid. This is consistent with nickel being in the form of the very insoluble nickel oxide, and suggests the other metals are also present as insoluble metal oxides or metal alloys. The availability of lead was only slightly higher, averaging 3.8%. Considering the rigorousness of the leach process, it was designed to mimic the conditions and residency time of the human GI tract, the very low leachability indicates that bioavailability is very low. That means only a very small fraction, generally less than 4%, of the total amount of the contaminant in the soil can interact with the environment.

Very low bioavailability would also explain the rarity of nickel injury symptoms on vegetation in the Rodney St. community specifically and the Port Colborne area in general. If less than 1% of the total nickel in the soil is removed by a simulated stomach acid leach than substantially less would be dissolved in ambient soil water. In order for nickel to injure vegetation it must be dissolved in soil water, taken up through the roots, and translocated throughout the plant. With such low bioavailability there would be very little dissolved nickel in soil water resulting in a small potential for vegetation uptake and injury. The low soil bioavailability would also explain the poor relationship between soil nickel levels and nickel levels in residential garden produce (i.e., the nickel levels in garden produce were not consistently higher from properties that had high soil nickel concentrations).

DISCUSSION

a) Soil Results for Residential Properties

Table A effects-based generic criteria (residential/parkland landuses - medium/fine textured soils) were exceeded in soil on one or more of the residential properties in the Rodney St. community for the following 10 inorganic parameters: antimony, arsenic, beryllium, cadmium, cobalt, copper, lead, nickel, selenium, and zinc (refer to Appendix Table A-1). Table A criteria

for lead, antimony, and beryllium are based on human health, the criterion for selenium is based on the protection of grazing animals, the criteria for arsenic, cadmium, cobalt, copper, nickel, and zinc are based on ecological protection, specifically plant growth. Table 2 summarizes the number of properties in the study area for which soil concentrations exceeded MOE Table A generic effects-based criteria and the human health risk-based soil intervention level, as determined by the MOE human health risk assessment (Part B of this report).

Table 2 shows that soil nickel concentrations exceeded the Table A generic criterion on all but one of the properties in the Rodney St. community. It was evident from the condition of this one property that it had undergone extensive landscaping, so the contaminated soil had either been buried below the 20 cm sampling depth, or had been removed and replaced with clean soil. Very elevated soil nickel levels were expected in this area, since the contaminant contour maps prepared for the 1998 and 1999 MOE Port Colborne soil investigations indicated that soil nickel concentrations could range up to 5,000 µg/g in this community. Similarly, soil cobalt and copper concentrations were expected to be high, and 61% and 54% of the properties, respectively, in the Rodney St. community exceeded the Table A criteria for these two elements. A high percentage (80%) of the properties sampled in this investigation also had soil lead levels above the Table A criterion. Surprisingly, soil beryllium levels on almost one half (49%) of the properties exceeded the Table A criterion. The effects-based criteria for arsenic and zinc were exceeded on about one quarter of the properties, 29% and 17%, respectively. Exceedences were rare for antimony, cadmium, and selenium, occurring on only 3 properties (2%) for antimony, and one property each (1%) for cadmium and selenium.

Sixteen properties (9% of the total) exceeded the nickel intervention soil level of 10,000 µg/g. Ten properties (6%) exceeded the 1,000 µg/g lead intervention level, and 56 properties (31%) exceeded the toddler-specific bare soil 400 µg/g lead intervention level. The human health risk assessment concluded that there were no intervention levels for the other eight elements that exceeded the MOE Table A criteria. An explanation of how these intervention levels were derived is provided in the *Part B Human Health Risk Assessment* portion of this report.

Statistical analysis was carried out on the samples collected from the two properties on each block that were sampled in triplicate (single samples were collected form all other properties). Within-site sampling/analytical variability was acceptable for most elements (excluding antimony and selenium), in that standard deviation of the replicates was less than <20% of the mean value for the property. The standard deviations of the replicate samples for antimony and selenium, expressed as percentages of the mean concentration, were 24.2% and 24.6%, respectively. The concentrations of both antimony and selenium are naturally very low in soil, usually less than 0.5 µg/g. The high variability between sample replicates for these two elements was related to the difficulty that the contract laboratory had in consistently obtaining detection limits that were in the 0.5 µg/g range.

To illustrate the spatial distribution of soil contamination in the Rodney St. community, contaminant contour maps were created for selected elements using Surfer and ArcView computer mapping programmes. Because of the technical complexities associated with creating

contour maps from a very large data base, and because no spacial pattern was evident for some elements, maps were created only for the elements that exceeded the MOE Table A guidelines and for which the guideline rationale was health-based. Therefore, maps were prepared for nine of the ten elements identified in Table 2. Zinc was excluded, because with few exceptions the exceedences of the Table A criteria were marginal, and the rationale for the guideline is not health-based. A separate contaminant contour map was produced for each of the three sampling depths (0-5 cm, 5-10 cm, and 10-20 cm) for the nine contaminants antimony, arsenic, beryllium, cadmium, cobalt, copper, lead, nickel, and selenium. These maps are located in Appendices B1 to B27.

These maps are a very helpful tool for identifying spacial trends, particularly for very large data sets, such as the 35,000 parameters generated by the 1,300 plus samples collected from the 179 properties from the Rodney St. community. Although useful and generally quite accurate, particularly with a high sampling density as used in this study, the contour maps are still only estimates of soil concentrations based on a statistical model. The actual soil concentration is known with certainty only at the sites where the samples were collected. In addition, the contaminant contours may be skewed towards the edges of the maps because there are no sample points beyond the map borders and the computer model cannot "close" the contour loops. This is particularly evident in the area south of Rodney St. where there were only a few samples from the trenches, and in the northeast corner of Louis and Davis Sts.

It is evident from the contaminant contour maps, and the data in Appendix A, that soil contamination in the Rodney St. community, although extensive for some elements, is very patchy. Properties with much lower soil contaminant levels were often encountered between properties with much higher concentrations. Conversely, single properties with significantly elevated concentrations of some elements were surrounded by properties with much lower contaminant levels. This patchwork pattern is characteristic of neighbourhoods that have experienced historic atmospheric deposition that resulted in fairly uniform soil contamination relative to distance and direction from the source, and with substantial abatement of emissions, continued deposition did not result in further accumulation of contaminants in the soil. Over time with property landscaping or redevelopment, the contaminated soil is either diluted by coverage with clean soil or removed and replaced by clean soil. Landscaping need not be elaborate to substantially alter the surface soil contaminant levels. Simply filling low spots in a lawn with topsoil or re-sodding can add enough clean soil to dilute the residual contamination. The contamination status of undisturbed properties remains unchanged to create the soil contamination patchwork pattern that was observed across the Rodney St. community.

Regardless of the patchiness some contaminant contour gradients were obvious. The most consistent were nickel, copper, cobalt, arsenic, and selenium. These five elements tended to be highest in the easterly and southeasterly areas of the Rodney St. community, adjacent to the INCO refinery. The patterns of nickel (Maps B22-B24), copper (Maps B16-B18), and cobalt (Maps B13-B15) soil contamination were particularly similar, with the higher concentrations restricted to properties along Rodney, Davis, and Mitchell Sts. The maximum soil nickel level was 17,000 μg/g detected in the 5-10 cm depth of a property on Rodney St. The maximum soil

copper concentration was 2,720 µg/g in a sample from the 10-20 cm depth of a Mitchell St. property. The highest soil cobalt concentration, also from a Mitchell St. property, was 262 µg/g in the 5-10 cm soil profile. Although properties with high nickel levels also had elevated copper and cobalt concentrations, the maxima for these elements did not occur on the same property. Soil nickel, copper, and cobalt concentrations tended to be slightly higher in the lower sample depths.

The patterns of soil arsenic (Maps B4-B6) and selenium (Maps B25-B27) contamination were similar, with the highest levels centred on Rodney St., with scattered properties along Mitchell St., and a few on Davis St. Unlike nickel, copper, and cobalt, which exceeded their respective Table A guidelines on the majority of properties in the Rodney St. community, the extent of arsenic and selenium contamination was much more restricted with concentrations that were proportionately much lower. The maximum soil arsenic concentration was 350 µg/g in the 0-5 cm depth from a property on Rodney St. However, most soil arsenic levels were much lower, generally considerably less than 100 µg/g, with 71% of the properties in the Rodney St. community being below the Table A guideline of 20 µg/g. Although a soil selenium gradient was evident, only 1 property had selenium levels that exceeded the Table A guideline with a maximum concentration of 19.4 µg/g in soil collected from the 5-10 cm depth of a property on Mitchell St. Soil selenium levels are naturally low and therefore any elevation above background is noticeable, a fact that allowed for a contaminant gradient to become evident. Even though soil beryllium levels exceeded the Table A guideline of 1.2 µg/g on 49% of the properties in the Rodney St. community, unlike the other 8 elements for which maps were constructed, the beryllium contaminant contour maps (Maps B7-B9) did not indicate any spacial pattern. The highest soil beryllium level was 4.6 µg/g, which was detected in the 10-20 cm depth at a property on Mitchell St. Like the other metals, soil beryllium levels tended to be slightly higher at depth.

The contaminant contour maps for lead (Maps B19-B21), and to a lesser degree for cadmium (Maps B10-B12) and antimony (Maps B1-B3), did not illustrate a spacial pattern relative to INCO or specific streets, but rather identified numerous apparently random "hot spots". Soil lead levels exceeded the MOE Table A guideline of 200 µg/g at 80% of the properties, whereas cadmium and antimony exceeded the MOE guidelines on 1% and 2% of the properties, respectively. Even though the three elements were spatially related to each other (same general patterns on the contour maps) the soil lead concentrations were far higher than either the cadmium or antimony levels and the maximum concentrations did not occur on the same properties. For example, the maximum soil lead level was 1,800 µg/g, which occurred on Mitchell St. The maximum soil antimony level was 35 µg/g, encountered on a Louis St. property. The maximum soil cadmium concentration was also 35 µg/g, which occurred on Davis St. Like the other metals, these elements tended to be slightly higher at depth.

b) Statistical Analysis of Chemical Relationships

Results of Pearson Product Correlation Tests on the soil data from all depths are summarized in

tabular form in Appendix C. Due to the very large number of degrees of freedom (1300 plus) all r values greater than 0.08 are significantly correlated at the 95% level. The higher the r value the stronger the correlation between the elements. Negative r values indicate an inverse relationship (i.e., one soil concentration increases as the other decreases).

Nickel, copper, and cobalt in surface soil in the Port Colborne area is unquestionably associated with INCO emissions. Of these three elements, nickel is a "signature" contaminant, meaning that it is present in the highest concentration, is the most extensive in area, and has the most consistent concentration gradient relative to distance and direction from INCO. Therefore, elements that are highly correlated with nickel are also likely related to INCO emissions. Aluminum is not associated with INCO emissions, or any other known current or historic pollution source in the area of the Rodney St. community, but it is the second most abundant element in the earth's crust. Therefore, elements that are highly correlated with aluminum are likely natural in origin.

Soil nickel concentrations in soil in the Rodney St community are very highly correlated with soil cobalt ® = 0.93), copper (r=0.87), iron (r=0.82), selenium (r=0.77), zinc (r=0.71), and arsenic (r=0.60) levels, suggesting that INCO emissions may also be the source of these elements. The high statistical correlation is corroborated by the contaminant contour maps which clearly illustrate a strong spacial relationship between nickel, copper, cobalt, and to a lesser extent arsenic and selenium (zinc and iron were not mapped). Previous MOE soil sampling in the Port Colborne area identified elevated soil copper and cobalt levels as having originated from INCO emissions. However zinc, arsenic, selenium, and iron levels in soil in areas other than the Rodney St. community have not been consistently elevated above MOE guidelines and there is little evidence of a spacial relationship to INCO.

Soil aluminum levels in the Rodney St. community are very highly correlated with vanadium (r=0.89) and beryllium (r=0.79). This, and the lack of a consistent soil spacial pattern, suggests the elevated beryllium concentrations detected on some properties are natural in origin.

Soil lead levels are highly correlated with zinc (r=0.75) and barium (r=0.74). These three elements are common components of older lead-based paint. Also, the historic use of leaded gasoline has substantially added to the soil lead levels in all urban areas. Even though lead was emitted from the INCO stack (it made up about 10% of the precipitator dust in the 1970s [13]) the lack of a consistent soil spacial pattern in the Rodney St. community suggests that most of the lead is associated with residential use of lead-based exterior paint.

Scatter plots were created to illustrate the relationship between nickel and many of the other elements (see Appendix C-1 to C-14). The scatter plots, in conjunction with the Pearson correlation coefficients (r>0.50) and principal component analysis suggest three distinct soil contaminant groupings in the Rodney St. community, with overlap for a few chemicals:

1) the nickel group, consisting of nickel, cobalt, copper, iron, selenium, zinc, and arsenic, are related to nickel with a correlation coefficient of at least 0.50,

2) the lead group, consisting of lead, zinc, barium, and copper, are related to lead with a correlation coefficient of at least 0.50, and

3) the aluminum group, consisting of aluminum, vanadium, and beryllium, are related to aluminum with a correlation coefficient of at least 0.50.

c) Results of Trench Samples

The results of chemical analysis of soil samples removed from the walls of the various trenches are summarized in Appendix Table A-2. Based on visual identification in the field, all seven of the trenches contained some fill material, including rocks, brick pieces, coal and coal ash, metal debris, cinders, slag, and unidentified coarse-textured lighter coloured material. The natural clay layer was encountered at about 1 metre in all trenches. The main contaminants in the trench soil were nickel, copper, cobalt, zinc, iron, and to a lesser lead, arsenic, and beryllium. The iron concentrations were quite elevated in some samples, ranging up to almost 17% (170,000 µg/g at 60 cm depth from the trench on the shoulder of Rodney St.). These high iron levels possibly reflect the abundance of metal debris observed in some trench layers.

The two trenches from the ball diamond park at the south end of Rodney St. were contaminated with nickel to the bottom of the trench, a depth of about 1 metre, with concentrations ranging from 304 µg/g to 6,680 µg/g. The maximum arsenic level was 33.1 µg/g , the maximum copper level was 524 µg/g, and the maximum cobalt concentration was 88.8 µg/g. The nickel, copper, cobalt, and arsenic levels all tended to be higher at depth. Most other elements, notably lead, were quite low.

The trench excavated on the shoulder of Rodney St. and the two trenches excavated in the vacant lot on the southwest corner of Rodney and Fares Sts. were similar in that the maximum contaminant levels tended to be closer to the surface. For example, in the Rodney St. trench the soil nickel levels ranged between 8,900 µg/g and 9,730 µg/g to approximately 35 cm and then dropped to 204 µg/g at approximately 60 cm. Similarly, the arsenic concentrations ranged from 30.7 µg/g and 43.1µg/g in the top 65 cm, then fell to background below this depth. The contaminant loading in the trenches from the vacant field tended to be lower than in the Rodney St. and ball diamond park trenches. Unlike the ball diamond park trenches, which had high nickel levels at all depths, the trench on the shoulder of Rodney St. and both trenches in the vacant field had the highest metal levels near the surface, with the layer of contamination abruptly ending between 30 and 60 cms.

The two trenches excavated in the parkette on the east side of Welland St. tended to have lower soil contaminant levels than the other trenches. Although nickel levels were elevated to the bottom in the west trench, all other contaminants were confined to the top 65 cm. Similarly, in the east trench all the contamination was confined to the top 65 cm, falling to virtually background levels below this depth. By comparison, the soil from the trenches from the two sodded berms located on the perimeter of the parkette's basketball court was much cleaner than

the other trenches. Only a few samples exceeded the MOE Table F background-based guidelines, and only a single sample exceeded the Table A effects-based guideline for beryllium.

Soil contamination was deepest in the baseball park, suggesting this area had received at least 1 m of metal-contaminated fill. Judging by the presence of debris in the other trenches, it was evident those areas had also been filled, although metal-contamination was mostly confined to the upper 30 to 60 cm. Therefore, outside of the baseball park metal-contaminated material was used as top-spread, rather than as fill, perhaps to level the ground in preparation for or subsequent to building. It is also possible that, outside of the obvious deep fill in the baseball park, the soil metal contamination in the area of the trenches is from atmospheric deposition because it is confined to the near surface layer. If this is the case, then the soil contamination in the Rodney St. community can be expected to extend to at least 30 cm in depth.

Soil Contamination: Source Allocation

The soil heavy metal levels in the Rodney St. community are higher than have currently been detected elsewhere in Port Colborne. The soil contamination could be related to 1) historic fugitive emissions from INCO, 2) INCO stack emissions, 3) emissions from other historic industries in the area (eg. Algoma Steel/Canada Furnace), 4) contaminated fill from local or unknown industrial, municipal or construction waste, 5) domestic residential sources, or 6) some combination of these.

The soil nickel, copper, and cobalt contamination documented in Port Colborne and the surrounding area in the 1998 and 1999 MOE investigations [1,2] is unquestionably related to long term atmospheric deposition of INCO's emissions. The area to the northeast of INCO is the zone of maximum deposition. The nickel:copper and nickel:cobalt soil ratios from this area are 9.9:1 (nickel:copper) and 56:1 (nickel:cobalt), and are remarkably consistent to soil ratios from all the samples collected in the Rodney St. community, 10.1:1 (nickel:copper) and 51:1 (nickel:cobalt), and the trench samples, 9.5:1 (nickel:copper) and 44:1 (nickel:cobalt). By comparison, using the natural background levels for Ontario soil (Table F in the MOE *Guideline for Use at Contaminated sites in Ontario* [6]) the ratios for these three elements in uncontaminated soil are 0.5:1 (nickel:copper) and 2.0:1 (nickel:cobalt), which illustrates the unique soil contaminant signature of INCO's Port Colborne refinery. This is very strong evidence that the nickel, copper, and cobalt contamination detected in the Rodney St. community is related to atmospheric emissions from INCO. Because of the very high correlation coefficients between nickel and arsenic ($r=0.60$), nickel and selenium ($r=0.77$), and nickel and zinc ($r=0.71$), the elevated concentrations of these three elements in soil in the Rodney St. community are concluded to have originated from INCO emissions. This is corroborated by the 1978 report [13] that identified arsenic as 0.38% (3,800 µg/g) and zinc as 0.14% (1,400 µg/g) of INCO's stack dust. However, soil zinc contamination can also be associated with residential sources, and so not all of the soil zinc contamination in the Rodney St. community is related to INCO.

The spacial distribution of the nickel, copper, cobalt, arsenic, selenium, and zinc soil contamination is consistent with a source to the south and east of the Rodney St. community, as the soil concentrations are highest on Rodney St. and Davis St., and to a lesser degree on Mitchell St. The zinc pattern tends to be a little more scattered but a southeasterly gradient is still apparent. In addition, the observation that the highest soil contaminant levels tended to be just below the surface in the 5-10 cm or even 10-20 cm depth is consistent with an atmospheric deposition source that was much greater in the past. With the cessation of atmospheric deposition heavy metals do move down through the surface soil, although this can take decades and the downward movement is usually only a few centimetres. If the amount of metal contaminant falling onto the soil were constant, the upper-most soil layer would have the highest metal concentration because the rate of accumulation at the surface exceeds the rate of downward percolation. Fugitive emissions from INCO in the early years of operation, particularly before the stack was constructed in 1929, would have been very substantial. The Rodney St. community is immediately adjacent to the refinery and would have been significantly impacted by high levels of atmospheric metal loading and deposition resulting in rapid accumulation of heavy metals in surface soil. When the stack was constructed, the fugitive emissions would have been somewhat abated and the rate of deposition to soil in the Rodney St. community would have been reduced. Eventually, the rate of accumulation in the surface soil fell below the rate of downward percolation resulting in a slow but consistent downward migration of the heavy metal contamination out of the top 5 cm of the surface soil and into the near-surface and sub-surface soil layers at a depth of 10 to 20 cm.

This is exactly the pattern observed in soil lead levels in Toronto. In the 1970s, lead from leaded gasoline combustion was ubiquitous in the Toronto airshed resulting in high ambient air lead levels and subsequent deposition and accumulation of lead in surface soil. MOE soil sampling confirmed the lead concentration in 0-5 cm surface soil in Toronto in 1971 averaged 196 µg/g and 125 µg/g in the 10-15 cm depth. Leaded gasoline was phased out in the early 1980s resulting in substantial reductions in ambient air lead levels and a virtual cessation of lead deposition to soil. A repeat sampling of the same sites in 1991 showed that with the elimination of lead deposition from the air the lead had moved down into the soil such that the lead levels in the 10-15 cm samples were higher (311 µg/g) than the 0-5 cm samples (185 µg/g).

The elevated lead levels in soil in the Rodney St. community are not related to INCO emissions. The pattern of lead contamination is not spatially similar to nickel, copper, or cobalt, and there is no southeasterly concentration gradient towards INCO. Instead high lead levels are randomly scattered throughout the community. Lead levels in soil are highly correlated with barium, copper, cadmium, cobalt, chromium, and zinc, and notably poorly correlated with nickel. These elements (nickel excepted) were common anti-mildew and anti-fungal additives in paint manufactured up to the mid 1970s. Previous Phytotoxicology investigations have clearly linked residential soil contaminated by these elements to the erosion, weathering, and/or removal of exterior leaded paint. Paint chips from flaking paint are often visible on the soil. Analysis of these chips collected from residential yards of older urban homes in Toronto showed that the paint contained up to 33% lead (310,000 µg/g), 12.4% zinc (124,000 µg/g), and 0.85% chromium (8,500 µg/g) [15]. The soil lead and zinc concentrations of these yards ranged up to

890 μg/g and 445 μg/g, respectively. Almost every year Phytotoxicology scientists assist MOE District Environmental Officers and local health unit inspectors in the investigation of blood lead poisoning of very young children. In almost every case the lead source is found to be lead-contaminated soil from flaking or eroded exterior lead-based paint.

On a few properties in the Rodney St. community high soil lead levels are spatially correlated with high soil antimony concentrations. Antimony is commonly alloyed with lead as a hardening agent, and was used extensively in battery manufacture, particularly automotive lead-acid batteries. Phytotoxicology investigations around secondary lead smelters that used lead-acid batteries in their feed stock and around battery manufacturers routinely identified soil lead and antimony contamination.

Lead is an ubiquitous soil contaminant that is generally higher in urban communities because of the historic use of leaded gasoline. The combination of historic deposition of lead from leaded gasoline and the chronic deposition of flaking and peeling exterior leaded paint has resulted in consistently elevated soil lead levels in urban communities across Ontario. Older urban communities have the highest soil lead levels because the soil has been exposed to greater numbers of vehicles for a longer period of time. In addition, older urban communities have older homes that may have been painted many times over the years, and therefore have had a longer time to accumulate weathered paint in the soil. In the Rodney St. community of Port Colborne 80% of the properties exceeded the MOE Table A generic effects-based soil lead guideline, and the average soil lead level was 222 μg/g. In Toronto the MOE has been monitoring environmental lead levels for 25 years in a community that has no known industrial source of lead pollution. In this community, which is similar to the Rodney St community in age and style of home construction, 78% of the residential properties exceed the MOE Table A lead criterion and the average soil lead level is 486 μg/g.

Soil lead concentrations in the 1,000 μg/g range, such as detected at a few scattered properties in the Rodney St. community, are entirely consistent with residential lead sources typical of older urban communities rather than related either to INCO emissions or contaminated fill material. Lead comprised 10.5% of the Cottrell Precipitator dust in 1978, and the precipitator dust nickel:lead ratio was approximately 4:1 [13]. If nickel and lead went up the stack in a 4:1 ratio then they should be present in soil downwind of the stack in about the same ratio. Based on the 1998 and 1999 MOE soil investigation reports in Port Colborne, at sample sites with soil nickel levels greater than 1,000 μg/g the average soil nickel level was 2,120 μg/g and the average soil lead concentration is 98 μg/g, which is a nickel:lead ratio of about 22:1. Similarly, the average soil nickel level in the Rodney St. community (excluding the trench data) is 2,545 μg/g, and the average soil lead concentration is 222 μg/g, for a nickel:lead ratio of 12:1. Clearly the soil lead levels in both the Rodney St. community and elsewhere in Port Colborne where soil nickel levels are elevated are much lower than anticipated if lead were co-emitted with nickel at the rate suggested by the precipitator dust. The 1978 document identifies nickel oxide as the most prevalent nickel compound, and lead sulphate as the most prevalent lead compound. Nickel oxide is very insoluble and therefore would not readily be leached from the soil. In contrast, lead sulphate is much more soluble and would likely be leached from the soil more readily than nickel

oxide. Current levels of lead in soil in Port Colborne in general, and the Rodney St. community specifically, have no spacial relationship relative to INCO and are not consistently statistically correlated with nickel. Although INCO emissions may have contributed to the overall soil lead burden in the Rodney St. community, historic vehicle emissions from the combustion of leaded gasoline and residential sources, such as weathered exterior lead-based paint, are both far more significant and known lead sources that could account entirely for the soil lead levels encountered in this study.

The MOE has recently become aware of circumstances where elevated concentrations of naturally-occurring beryllium were found to be associated with shale deposits. In view of the suspected toxicity of the metal, the presence of numerous deposits of shale in Ontario, and the practice of using shale as fill material, in 1997 MOE Phytotoxicology scientists undertook a province-wide sampling program of representative shale deposits in Ontario. Seven of the 12 shale formations sampled, or 58%, had beryllium concentrations in the shale rock and the adjacent soil overburden that exceeded the MOE Table A health-based guideline of 1.2 µg/g [5].

Although the average soil beryllium concentration in the Rodney St. community was 0.98 µg/g, which is consistent with typical Ontario background levels, a surprising number of properties (49%) had soil beryllium concentrations that exceeded the MOE Table A guideline (1.2 µg/g). The highest beryllium concentration found in the province-wide shale study was 3.4 µg/g, detected in samples collected from the Animikie-Gunflint shale formation in the Thunder Bay area. The Queenston and Rockcliffe shale formations, closer to Port Colborne, had beryllium concentrations ranging up to 2.3 µg/g. Only two soil samples of the 1,300 samples collected from the Rodney St. community had beryllium levels greater than 2.3 µg/g. The marginally elevated soil beryllium levels in this community are entirely consistent with naturally-occurring beryllium in soil derived from shale, although the number of properties with beryllium concentrations higher than the provincial background was unexpected. In addition, the soil beryllium concentrations in the Rodney St. community are very highly correlated with soil aluminum levels ($r=0.79$, $p<0.001$), which implies the beryllium is natural in origin.

Slag has a beryllium concentration that routinely ranges from 1 to 3 µg/g. Historic photographs of the Rodney St. community show most of the roads in place by 1917. Anecdotal information suggests that slag was a common material for roadbed construction in this community. Slag was observed on road shoulders, in some of the trench samples, and was frequently encountered while sampling the residential properties. Slag was identified in the scanning electron microscope photographs of soil samples collected from several Rodney St. properties. It is evident that slag is present at the surface in the Rodney St. community, and this presence could also account for the generally higher than expected soil beryllium levels.

The highest soil beryllium concentration detected in the Rodney St. community was 4.6 µg/g, which occurred at the same property that had significantly elevated soil lead levels (877 µg/g). This property also had high arsenic, barium, nickel, cobalt, copper, and zinc concentrations. Although soil lead levels and soil beryllium levels across the Rodney St. community are not highly correlated ($r=0.29$), the spacial relationship between beryllium and lead at this single

property is not likely co-incidental (compare beryllium Maps B7, B8, and B9 with lead Maps B190, B20, and B21 in Appendix B). It is certain that the beryllium levels on this property are not related to INCO emissions because the statistical relationships between soil beryllium and soil nickel (r=0.08), copper (r=0.16), and cobalt (r=0.11) are less significant than the beryllium and lead relationship. In addition, beryllium and arsenic soil levels are actually inversely related (negative correlation coefficient, r = -0.03, as arsenic levels increase beryllium levels decrease, and visa versa). Soil beryllium levels are more highly correlated with barium (r=0.60) than with antimony (r=0.10), which suggests that the elevated lead and beryllium levels on this property are related to paint rather than batteries. Although the high beryllium levels in soil on this property appear to be related to leaded paint, that is not the case elsewhere in the Rodney St. community because other than this single property there is no consistent spacial relationship between soil beryllium and soil lead concentrations. With the exception of this one property, the marginally elevated beryllium levels in soil in the Rodney St. community are a combination of high natural levels because of local shale deposits and slag.

Conclusions

The average soil nickel concentration in the Rodney St. community was 2,545 µg/g. This is consistent with the 1998 and 1999 MOE soil investigations that predicted this area of Port Colborne could have between 2,000 µg/g and 4,000 µg/g nickel in surface soil. However, property by property sampling revealed substantial variation in both the numbers of contaminants and the soil contaminant concentrations. Of the 1,300 plus samples collected from 179 properties, 99% of the properties had soil nickel levels that exceeded the MOE Table A effects-based criterion of 200 µg/g and 16 properties (about 9%) exceeded the 9,750 µg/g risk-based value used in the 1997 MOE/Regional Niagara Public Health Department Human Health Risk Assessment report. The maximum soil nickel level was 17,000 µg/g. In addition to nickel, the MOE Table A guidelines were exceeded for lead on 80% of the properties, cobalt on 62% of the properties, copper on 54% of the properties, beryllium on 49% of the properties, arsenic on 29% of the properties, zinc on 17% of the properties, antimony on 2% of the properties, and 1 % of the properties had soil levels exceeding the selenium and cadmium MOE guidelines. For most elements on most properties, the soil contaminant concentrations tended to increase with depth. If the trenches excavated in the vacant lot south of Rodney St. and the park east of Welland St. are representative of the soil profiles across the community then soil contamination on residential properties in the Rodney St. community may extend to 30 cm, but should rapidly fall to background levels below that depth.

Soil nickel, copper, cobalt, and arsenic contamination in the Rodney St. community is unquestionably related to INCO. Because of the high degree of spacial and statistical relationship with these four elements, elevated soil selenium and possibly zinc levels are also likely related to INCO. Although there is evidence to suggest that the baseball park at the southeast corner of Rodney and Davis Sts. may have been created from metal-contaminated fill, the source of the soil nickel, copper, cobalt, arsenic, and to a lesser degree selenium and zinc contamination, across the community is believed to be fugitive INCO emissions that occurred

early in the refinery's operating history, perhaps before the construction of the stack in 1929. Although some post-stack fugitive and stack emissions likely contributed to the soil metal contamination, atmospheric heavy metal deposition to the Rodney St. community would have been reduced after 1929. The height of the stack, in conjunction with the strong non-snow season southwesterly prevailing winds, dispersed most of the emissions to the northeast after the stack was built.

The highest soil nickel, copper, cobalt, arsenic, selenium, and zinc soil concentrations occurred on properties in the southeastern area of the Rodney St. community along Rodney, Mitchell, and Davis Sts. Based on the contaminant contour maps it is likely that elevated soil metal levels may extend slightly further along Davis St. north of Louis St. Further soil sampling is also warranted in the residential communities immediately adjacent to the north northwest, north, and north northeast of INCO, to ensure the previous MOE investigations have not underestimated the soil metal levels in these areas of Port Colborne.

The randomly scattered soil lead contamination observed in the Rodney St. community is related to domestic residential lead sources and not to INCO emissions. The erosion and flaking of old lead-based paint from exterior structures such as house and shed walls, porches, fences, poles, and playground equipment is a common source of soil lead contamination in older urban communities. The soil lead levels found in the Rodney St. community are not unique either in extent or concentration. On properties where the soil lead levels were elevated the concentrations of cadmium, chromium, copper, barium, and zinc often were proportionately elevated. Along with lead, these elements were common pigment, anti-mildew, or anti-fungal additives in old exterior paint and are frequent co-contaminants in residential soil. Antimony was another element that was highly correlated with lead, although it exceeded MOE guidelines on only 3 properties. Antimony is commonly alloyed with lead, particularly in lead-acid batteries. Lead and antimony soil contamination is an indication that batteries may have been stored or disposed of on the property, whereas lead and barium, and lead and zinc soil contamination is a signature of lead-based paint.

Although the average soil beryllium level in the Rodney St. community was comparable to the provincial soil background concentration, almost one-half of the properties exceeded the MOE Table A guideline. Soil beryllium levels marginally above the guideline are not unusual, because the guideline and the upper end of the background range are the same (1.2 µg/g). Also, MOE investigations have documented that shale, and soil derived from shale, regularly exceed the guideline. In addition, slag has a beryllium concentration that is above the guideline, and slag is present at the surface across the Rodney St. community. With the exception of one property where elevated beryllium levels were concurrent with high lead and other heavy metals, the marginally elevated soil beryllium concentrations across the Rodney St. community are related to the presence of slag and local shale deposits.

Considerable variability in soil contaminant levels was evident between adjacent properties. This "patchwork" pattern of high and low soil contamination on neighbouring lots is related to property maintenance and landscaping. Adding topsoil or mulch, re-sodding, building, and

cultivated gardens are landscaping practices that, over time, tend to cover or dilute contaminants that are predominantly present in the surface soil. It also indicates that the source of the soil contamination is likely atmospheric and that with recent deposition substantially decreased, newly landscaped properties have not become re-contaminated to the levels of undisturbed properties.

The bioavailability of the soil contaminants found in the Rodney St. community is very low, in the range of 1% for most metals and up to 3.8% for lead. This means the contaminants are relatively immobile in the soil, so they are not easily dissolved in soil water and therefore are not readily taken up by plants. This low Bioavailablity accounts for the remarkably minor amount of nickel injury observed on species of vegetation known to be sensitive to nickel in areas of Port Colborne where the soil nickel levels are substantially above the MOE ecotox-based soil guideline. Most, if not all, of the nickel in soil in Port Colborne is present as nickel oxide.

With the cessation of atmospheric deposition, contaminants should no longer accumulate at the soil surface and the fact that soil contaminant levels in the Rodney St. community tend to be higher in subsurface soil layers is a further indication that the sources of contamination are historic. However, this does not imply that over time the contaminants will continue to move downwards in the soil profile and eventually be deep enough so that they no longer pose a potential ecological or human health concern. Soil is a dynamic chemical, mechanical, and biological ecosystem, and at the microcosm scale, soil is constantly in flux. Limited MOE studies in other communities where soil has been contaminated by historic industrial air emissions have indicated that soil contaminants can move upwards through the soil column with soil water through evapotranspiration and they can move downwards through the soil by gravity and soil water percolating down through soil pores, root, and insect channels. In addition soil contaminants can be brought back to the surface from considerable depth as a result of tunnelling by ants, earthworms, and other soil macro- and microorganisms. The result is that over time, likely decades, soil contaminants that originated on the surface tend to get uniformly mixed into the top 30 or so centimetres of soil.

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Table 1: Summary of soil pH and Percent Leach* Data (means of ten soil samples)

Chemical Parameter	**0 - 5 cm depth**	**5 - 10 cm depth**	**10 - 20 cm depth**
Mean Soil pH	7.19	7.23	7.49
	Mean Total Soil Concentration (µg/g)	**Mean Leach Soil Concentration (µg/g)**	**% Leach Estimate of Bioavailablity**
Aluminum	8780	108	1.3
Antimony	2.28	0.0031	0.14
Arsenic	48	0.53	1.1
Barium	159	4.8	3.2
Cadmium	0.2<W	0.006	nc
Calcium	21700	992	4.61
Chromium	41	0.21	0.51
Cobalt	174	1.64	0.96
Copper	897	17	1.9
Iron	84600	209	0.26
Lead	361	13.7	3.8
Magnesium	6940	251	3.56
Manganese	1016	33	3.23
Nickel	12600	101	0.82
Selenium	8.6	nc	nc
Strontium	71	2.9	4.03
Vanadium	33	0.36	1.1
Zinc	918	20	2.21

* simulated stomach acid leach
nc - not calculated, leach data below analytical detection limit

Table 2: Number and percentage of properties in the Rodney St. community with soil concentrations exceeding MOE Table A generic criteria and human health-based risk levels in one or more of the three sampling depths (0-5cm, 5-10cm or 10-20cm). Total number of properties is 179.

Chemical Parameter	Number of properties where soil exceeds Table A criterion	Percentage of properties where soil exceeds Table A criterion	Number of properties where soil exceeds intervention level	Percentage of properties where soil exceeds intervention level
Antimony	3	2%	0	0%
Arsenic	51	29%	0	0%
Beryllium	87	49%	0	0%
Cadmium	1	1%	0	0%
Cobalt	110	62%	0	0%
Copper	97	54%	0	0%
Lead	143	80%	10[1] (56)[2]	6% (31%)
Nickel	178	99%	16[3]	9%
Selenium	1	1%	0	0%
Zinc	30	17%	0	0%

1 - 1,000 µg/g
2 - 400 µg/g
3 - 10,000 µg/g
See **Part B Human Health Risk Assessment** for an explanation of the soil intervention levels.

Table 3: Ratios of Nickel, Copper, and Cobalt from Three Areas in Port Colborne

Area	Mean Soil Metal Concentration (µg/g)			Metal Soil Ratios	
	Ni	Cu	Co	Ni:Cu	Ni:Co
NE of INCO[1]	1809	182	32	9.9:1	56:1
Rodney St. Community[2]	2545	250	50	10.1:1	51:1
Trench Samples[3]	1401	148	32	9.5:1	44:1
Natural Background[4]	43	85	21	0.5:1	2.0:1

1 - mean of 8 1998/1999 MOE sample sites to the NE of INCO in the maximum deposition zone
2 - mean of all Rodney St. Community samples
3 - mean of all trench samples, excluding the park berms
4 - MOE Table F

Appendix A: Results of Chemical Analysis

Interpretation of Table A1 and A2

The results of the analysis for twenty inorganic parameters in soil from the 179 residential properties in the Rodney St. Community west of INCO sampled in the fall of 2000 are summarized in Table A1. In order to fit all of the results from each sampling location onto one table for comparison purposes, the standard chemical abbreviation had to be used. To help interpret the data in Table A1 the chart below gives the full chemical name and it's standard chemical abbreviation.

Chemical	Abreviation	Chemical	Abreviation	Chemical	Abreviation
Aluminum	Al	Antimony	Sb	Arsenic	As
Barium	Ba	Beryllium	Be	Cadmium	Cd
Calcium	Ca	Chromium	Cr	Cobalt	Co
Copper	Cu	Iron	Fe	Lead	Pb
Magnesium	Mg	Manganese	Mn	Molybdenum	Mo
Nickel	Ni	Selenium	Se	Strontium	Sr
Vanadium	V	Zinc	Zn		

Bold faced and underlined data exceed the MOE Table A generic effects-based guideline for residential/parkland landuses, medium/fine textured soils.

An asterisk (*) in the soil depth column, indicates the sample was analyzed more that once for quality assurance purposes and the results reported are the average of all of the analysis.

"nd" indicates no data, either because the sample was lost or the container broke.

Soil from the 17 Rodney St. properties was not analyzed for antimony ("na"), as these samples were collected and analyzed before the other properties in the general Rodney St. community were collected.

Table A1: Chemical analysis of soils collected in the fall of 2000

Site / Location	Soil Depth	Al	Sb	As	Ba	Be	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	Sr	V	Zn
2022013 (Front yard)	0-5 cm	5200	na	**35.0**	100	<0.25	0.50	11000	35	**120**	**510**	58000	**290**	3200	800	2.1	**6400**	5.70	41	24	660
	0-5 cm	5200	na	**37.0**	110	<0.25	0.70	12000	37	**110**	**470**	53000	**300**	3400	800	2.2	**5500**	5.70	38	24	620
	5-10 cm	5500	na	**65.0**	130	0.6	<0.10	9900	49	**220**	**990**	130000	**400**	3200	1200	3.7	**16000**	6.90	37	34	**1100**
	5-10 cm	5800	na	**110.0**	140	0.6	0.40	11000	44	**150**	**770**	90000	**480**	3300	1100	3.0	**9200**	8.70	41	29	**990**
	10-15 cm	7300	na	**30.0**	99	<0.25	<0.10	11000	19	**57**	**430**	38000	190	4000	560	<0.25	**4900**	3.90	36	24	420
	10-15 cm	7500	na	**42.0**	140	0.6	<0.10	12000	36	**84**	**660**	51000	**240**	3900	740	1.4	**7100**	5.10	42	25	620
	15-20 cm	7100	na	18.0	90	<0.25	0.50	17000	20	30	200	26000	100	4400	400	1.3	**2100**	2.50	45	21	260
	15-20 cm	6800	na	13.0	78	<0.25	0.30	16000	15	18	130	17000	140	4000	300	<0.25	**1200**	2.10	42	19	170
2022014 (Back yard)	0-5 cm	7800	na	15.0	67	<0.25	0.50	14000	22	48	210	30000	93	4800	470	0.8	**2400**	2.80	49	24	340
	0-5 cm	6700	na	20.0	68	<0.25	0.60	14000	24	49	240	30000	99	4700	500	1.2	**2600**	3.80	49	21	330
	5-10 cm	5900	na	20.0	74	<0.25	0.40	15000	23	**58**	260	31000	110	4500	490	1.1	**2800**	3.90	59	21	390
	5-10 cm	5500	na	**32.0**	87	<0.25	<0.10	16000	28	**96**	**420**	53000	170	4400	640	1.5	**5100**	8.70	64	24	520
	10-15 cm	6800	na	**28.0**	100	0.6	0.50	20000	29	**110**	**390**	45000	180	5400	650	1.9	**4300**	5.20	86	28	550
	10-15 cm	5600	na	**29.0**	99	<0.25	0.40	16000	27	**100**	**410**	47000	**220**	3700	650	1.5	**4400**	5.50	82	26	550
	15-20 cm	7900	na	**39.0**	150	0.7	0.50	25000	35	**150**	**580**	56000	**260**	5700	930	2.3	**5600**	5.80	140	32	720
	15-20 cm	5500	na	**38.0**	100	<0.25	<0.10	18000	24	**110**	**410**	50000	**240**	3700	610	1.0	**5500**	5.50	87	27	600
2022501 (Front yard)	0-5 cm	7100	na	14.0	90	<0.25	0.90	16000	19	36	160	26000	98	6800	530	0.8	**1700**	2.70	42	23	320
	0-5 cm	8100	na	13.0	80	0.6	1.00	17000	20	39	170	27000	110	7200	550	0.6	**1700**	2.80	45	26	330
	5-10 cm	7100	na	16.0	72	<0.25	1.10	17000	23	41	180	30000	95	7000	550	0.9	**1800**	2.80	41	25	340
	5-10 cm	8400	na	15.0	82	0.6	1.10	18000	21	44	190	29000	110	7400	580	0.8	**1800**	2.60	47	27	360
	10-15 cm	8700	na	18.0	87	0.6	0.90	20000	22	**56**	250	35000	120	7700	670	<0.25	**2800**	2.80	49	29	430
	10-15 cm	8800	na	18.0	93	0.7	1.10	20000	26	50	230	32000	120	7600	650	1.2	**2300**	3.30	51	28	410
2022502 (Back yard)	0-5 cm	10000	na	23.0	100	0.6	1.10	8400	30	**58**	260	40000	130	3900	700	1.4	**3100**	4.60	26	32	410
	0-5 cm	9500	na	19.0	84	0.6	0.90	8800	29	**51**	240	36000	120	3800	620	<0.25	**2700**	4.20	27	29	360
	5-10 cm	10000	na	26.0	89	0.6	0.80	7500	30	**57**	290	42000	120	3900	690	1.1	**3300**	5.10	23	31	400
	5-10 cm	10000	na	23.0	86	0.6	0.50	8700	32	**57**	290	44000	130	3900	720	1.4	**3300**	5.00	26	31	430
	10-15 cm	16000	na	16.0	110	0.8	0.80	6900	30	42	180	35000	84	4800	700	0.8	**2200**	3.40	23	39	270
	10-15 cm	13000	na	16.0	93	0.7	0.70	9700	31	49	220	38000	110	4800	660	0.9	**2800**	2.80	27	34	330
2022601 (Front yard)	0-5 cm	8700	na	11.0	83	<0.25	0.40	15000	17	38	170	24000	100	5700	400	0.8	**1900**	2.30	71	25	250
	0-5 cm	8500	na	10.0	77	<0.25	0.40	14000	17	34	150	22000	94	5400	370	<0.25	**1600**	2.40	58	23	230
	5-10 cm	6600	na	22.0	87	<0.25	0.60	18000	25	**63**	280	36000	120	6700	540	1.3	**3100**	3.70	88	27	350
	5-10 cm	8600	na	20.0	100	0.6	0.60	18000	23	**70**	300	34000	130	6800	590	1.1	**3200**	3.90	84	29	340
	10-15 cm	6100	na	**43.0**	88	<0.25	0.30	16000	34	**110**	**500**	55000	160	5700	750	1.9	**5700**	4.70	78	28	590
	10-15 cm	7300	na	**45.0**	120	0.6	0.40	18000	36	**150**	**640**	72000	180	6200	870	2.6	**8400**	5.40	80	32	610

Table A1: Chemical analysis of soils collected in the fall of 2000

Site / Location	Soil Depth	Al	Sb	As	Ba	Be	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	Sr	V	Zn
2022602 (Back yard)	0-5 cm	10000	na	5.6	78	<0.25	0.60	35000	16	20	61	17000	61	1100	430	<0.25	**330**	1.00	120	26	110
	0-5 cm	10000	na	4.2	73	<0.25	0.50	32000	16	18	50	16000	53	1000	390	<0.25	**300**	1.00	120	26	98
	5-10 cm	8700	na	5.9	66	<0.25	0.60	30000	15	29	82	15000	77	1100	380	<0.25	**580**	1.60	97	26	110
	5-10 cm	8500	na	5.4	62	<0.25	0.50	29000	15	17	55	15000	57	1000	320	<0.25	**380**	1.20	92	26	91
	10-15 cm	9700	na	6.1	83	0.6	0.40	35000	17	25	85	16000	79	1200	350	<0.25	**570**	1.30	130	28	110
	10-15 cm	14000	na	10.0	120	0.9	1.50	37000	25	**51**	170	25000	170	1300	490	1.1	**1200**	2.70	250	40	260
2022701 (Front yard)	0-5 cm	8800	na	15.0	88	<0.25	0.80	11000	20	41	190	28000	150	3900	430	<0.25	**2200**	3.40	46	23	350
	0-5 cm	8400	na	15.0	86	<0.25	0.70	10000	23	41	180	28000	140	3900	410	1.3	**2200**	3.50	45	23	330
	5-10 cm	9100	na	18.0	88	<0.25	0.60	9400	27	46	220	32000	150	3700	470	0.9	**2700**	3.80	41	24	360
	5-10 cm	9500	na	24.0	120	0.6	0.80	11000	32	**68**	**320**	44000	200	4100	550	1.6	**4300**	5.20	47	27	500
	10-15 cm	6700	na	**27.0**	110	<0.25	0.70	13000	21	47	280	32000	**210**	4300	470	1.5	**3200**	5.20	48	20	440
	10-15 cm	7000	na	**39.0**	120	<0.25	1.00	13000	27	**60**	**340**	42000	**250**	3800	600	0.9	**4100**	5.90	53	21	590
2022702 (Back yard)	0-5 cm	9100	na	14.0	110	<0.25	0.90	6800	21	47	210	23000	170	2600	350	0.8	**2400**	3.70	39	24	370
	0-5 cm	8300	na	13.0	100	<0.25	0.60	6000	18	36	160	19000	130	2300	280	0.8	**1700**	3.60	36	20	330
	5-10 cm	12000	na	21.0	130	0.6	1.10	7100	29	**61**	270	32000	180	3000	450	1.1	**3000**	4.60	43	30	460
	5-10 cm	12000	na	15.0	130	0.6	0.90	6900	25	49	220	27000	150	2900	390	1.1	**2500**	3.70	42	28	390
	10-15 cm	12000	na	20.0	130	0.6	1.20	7500	27	**58**	280	33000	180	3100	440	<0.25	**3000**	4.40	47	28	440
	10-15 cm	12000	na	20.0	150	0.7	1.20	7700	29	**60**	280	34000	190	3300	470	0.8	**3200**	4.30	49	30	450
2022801 (Front yard)	0-5 cm	8400	na	11.0	75	<0.25	0.40	13000	18	33	140	24000	90	5400	460	0.8	**1700**	2.00	40	25	200
	0-5 cm	8000	na	9.5	76	<0.25	0.50	14000	16	33	140	23000	86	5500	420	1.1	**1600**	2.10	41	24	190
	5-10 cm	7600	na	**26.0**	92	0.6	0.60	16000	26	**66**	300	45000	170	6000	650	1.6	**3800**	4.10	61	26	460
	5-10 cm	7800	na	23.0	95	0.6	0.30	17000	25	**71**	300	45000	170	6200	610	1.4	**4100**	4.00	52	27	400
	10-15 cm	7700	na	**34.0**	97	0.6	<0.10	17000	31	**91**	**410**	61000	180	5700	710	2.3	**6200**	4.80	59	28	540
	10-15 cm	8900	na	24.0	110	0.7	0.30	19000	20	**59**	300	36000	150	6400	550	0.7	**4000**	3.90	64	28	340
2022802 (Back yard)	0-5 cm	15000	na	13.0	120	1	0.70	35000	27	**56**	190	27000	130	1400	490	1.0	**1700**	2.80	170	39	210
	0-5 cm	14000	na	15.0	120	1	0.60	38000	25	**59**	210	29000	140	1400	530	<0.25	**1900**	3.10	190	37	240
	5-10 cm	18000	na	13.0	140	1.1	0.50	37000	29	44	160	28000	120	1500	460	0.6	**1400**	2.70	190	41	190
	5-10 cm	18000	na	12.0	140	1.1	0.60	46000	30	41	170	29000	120	1700	500	1.0	**1300**	2.40	240	40	180
	10-15 cm	19000	na	10.0	140	1.1	0.50	43000	69	29	120	27000	89	1500	420	9.8	**940**	2.10	260	43	140
	10-15 cm	20000	na	11.0	150	1.2	0.70	49000	28	31	140	27000	99	1800	470	0.9	**1100**	2.00	210	42	170

Table A1: Chemical analysis of soils collected in the fall of 2000

Site / Location	Soil Depth	Al	Sb	As	Ba	Be	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	Sr	V	Zn
2022901 (Front yard)	0-5 cm	8200	na	14.0	100	<0.25	0.50	7200	22	36	140	20000	96	2900	290	<0.25	**1700**	1.70	27	22	240
	0-5 cm	7900	na	13.0	81	<0.25	0.50	7300	16	34	130	20000	87	3000	280	0.6	**1600**	1.90	27	22	230
	5-10 cm	7000	na	18.0	85	<0.25	0.30	8400	19	**52**	200	29000	120	3300	390	1.0	**2600**	2.80	27	23	320
	5-10 cm	8800	na	14.0	99	<0.25	0.50	8200	19	48	180	24000	120	3300	380	1.0	**2300**	1.80	29	24	300
	10-15 cm	7500	na	**62.0**	130	0.6	0.40	14000	32	**97**	**470**	55000	**230**	4700	710	1.8	**5800**	5.60	46	28	690
	10-15 cm	7300	na	**60.0**	130	0.6	0.40	13000	33	**100**	**480**	59000	**230**	4400	720	2.2	**6000**	6.30	42	27	710
2023001 (Front yard)	0-5 cm	6700	na	16.0	140	<0.25	0.90	79000	45	47	220	29000	**240**	5900	430	1.3	**2400**	2.90	580	22	400
	0-5 cm	7500	na	16.0	140	0.6	1.10	91000	21	45	210	29000	**200**	5800	450	0.8	**2200**	3.20	690	24	380
	5-10 cm	6200	na	24.0	150	0.6	0.30	77000	26	**72**	**340**	48000	**220**	5600	580	1.6	**4700**	4.30	590	26	480
	5-10 cm	6800	na	**33.0**	160	0.6	0.60	74000	25	**73**	**400**	48000	**250**	6200	670	1.4	**4500**	4.90	560	26	550
	10-15 cm	5700	na	**39.0**	180	0.6	0.50	39000	28	**79**	**480**	50000	**320**	5400	690	1.6	**5500**	5.10	270	25	650
	10-15 cm	5800	na	**40.0**	190	0.6	<0.10	34000	32	**110**	**550**	68000	**330**	6700	830	2.0	**8000**	4.10	220	28	730
2023101 (Front yard)	0-5 cm	4800	na	14.0	77	<0.25	0.40	12000	17	33	180	18000	130	4100	310	1.2	**1700**	2.60	31	17	280
	0-5 cm	4300	na	14.0	68	<0.25	1.00	10000	17	29	150	18000	110	3500	300	0.8	**1500**	2.40	27	16	250
	5-10 cm	4400	na	19.0	92	<0.25	<0.10	14000	19	**52**	260	28000	170	4400	420	0.8	**2800**	3.00	34	19	380
	5-10 cm	4400	na	15.0	94	<0.25	0.40	14000	19	**55**	280	32000	180	4400	440	1.1	**3200**	2.90	36	22	380
	10-15 cm	5000	na	18.0	120	<0.25	<0.10	16000	23	**72**	**360**	48000	200	4800	570	1.5	**5100**	3.40	43	33	470
	10-15 cm	4300	na	17.0	120	<0.25	<0.10	15000	20	**58**	**330**	34000	180	4500	460	1.0	**4000**	3.00	38	23	400
2023102 (Back yard)	0-5 cm	4100	na	22.0	100	<0.25	0.30	9500	21	**64**	**330**	38000	**250**	2600	490	1.4	**4000**	4.40	39	20	500
	0-5 cm	3700	na	22.0	100	<0.25	<0.10	8300	18	**63**	**320**	33000	**270**	2100	470	1.3	**3900**	5.80	36	17	480
	5-10 cm	4200	na	**36.0**	120	<0.25	<0.10	10000	26	**91**	**460**	52000	**330**	2700	610	1.6	**6100**	5.50	43	24	610
	5-10 cm	4400	na	**37.0**	120	<0.25	0.30	9700	28	**95**	**480**	56000	**310**	2400	640	2.4	**6100**	5.60	42	25	630
	10-15 cm	4200	na	**39.0**	130	<0.25	<0.10	11000	31	**88**	**460**	48000	**360**	2500	630	2.3	**6100**	5.80	51	22	600
	10-15 cm	3900	na	**44.0**	110	<0.25	<0.10	9900	21	**91**	**420**	45000	**310**	2400	540	1.6	**6400**	5.40	41	20	540
2023201 (Front yard)	0-5 cm	10000	na	**30.0**	120	0.7	0.30	19000	27	**79**	**350**	41000	160	6200	640	1.6	**4200**	5.80	66	31	420
	0-5 cm	9600	na	**26.0**	120	0.7	0.40	19000	28	**84**	**360**	46000	170	6400	680	3.2	**4400**	5.50	57	31	450
	5-10 cm	10000	na	**37.0**	120	0.7	<0.10	18000	29	**86**	**410**	48000	160	5500	690	1.5	**5800**	6.50	64	29	460
	5-10 cm	9700	na	**49.0**	120	0.7	<0.10	17000	31	**110**	**480**	61000	200	5400	750	1.7	**7700**	5.80	56	31	520
	10-15 cm	11000	na	20.0	180	1.1	<0.10	32000	17	50	300	36000	130	6100	680	<0.25	**4300**	3.90	97	28	320
	10-15 cm	13000	na	28.0	240	**1.5**	<0.10	40000	18	**63**	**430**	39000	180	6500	850	0.6	**5400**	4.80	120	28	420

Table A1: Chemical analysis of soils collected in the fall of 2000

Site / Location	Soil Depth	Al	Sb	As	Ba	Be	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	Sr	V	Zn
2023202 (Back yard)	0-5 cm	8900	na	11.0	96	<0.25	0.50	13000	17	30	140	21000	100	3800	440	0.9	**1500**	2.60	37	27	240
	0-5 cm	8700	na	9.9	110	<0.25	0.60	14000	17	26	120	19000	110	3800	440	0.8	**1300**	2.90	38	25	220
	5-10 cm	7300	na	12.0	92	<0.25	0.30	17000	18	36	170	24000	140	4000	460	<0.25	**2000**	2.50	44	28	260
	5-10 cm	7300	na	10.0	80	<0.25	0.40	18000	16	29	120	22000	110	3600	440	<0.25	**1500**	2.10	42	26	190
	10-15 cm	5800	na	**30.0**	100	<0.25	0.40	12000	21	**51**	240	33000	160	3900	410	0.9	**3000**	5.00	37	29	370
	10-15 cm	5700	na	18.0	93	<0.25	0.60	14000	22	40	190	24000	**210**	3600	370	0.8	**2200**	4.00	39	26	280
2023301 (Front yard)	0-5 cm	5900	na	**37.0**	99	0.6	<0.10	16000	31	**140**	**540**	67000	**220**	5800	830	2.4	**7000**	5.90	40	30	590
	0-5 cm	6200	na	**61.0**	110	0.6	0.40	16000	42	**170**	**670**	78000	**240**	5600	1000	3.2	**8000**	8.10	43	34	700
	5-10 cm	6100	na	**85.0**	120	0.6	<0.10	14000	46	**230**	**970**	130000	**360**	5500	1100	3.9	**17000**	7.90	37	30	**1000**
	5-10 cm	5900	na	**78.0**	94	<0.25	0.30	16000	32	**120**	**640**	66000	**290**	5900	800	2.9	**8800**	7.40	37	24	700
	10-15 cm	5900	na	25.0	70	<0.25	<0.10	21000	19	**72**	**350**	45000	130	6700	500	1.6	**5100**	3.70	44	22	360
	10-15 cm	5700	na	25.0	67	<0.25	<0.10	19000	15	**51**	280	32000	95	6700	420	0.8	**3500**	4.40	37	19	290
2023302 (Back yard)	0-5 cm	4700	na	19.0	68	<0.25	<0.10	7300	22	**84**	290	39000	140	2000	490	1.2	**3500**	4.40	25	26	360
	0-5 cm	3900	na	**29.0**	65	<0.25	<0.10	6200	22	**84**	280	30000	120	1400	450	1.7	**3100**	4.80	24	17	310
	5-10 cm	4700	na	**55.0**	100	<0.25	0.30	9400	34	**110**	**500**	66000	**330**	2100	660	2.6	**6800**	6.20	31	23	630
	5-10 cm	3900	na	**30.0**	69	<0.25	<0.10	5500	25	**66**	**330**	41000	140	1400	470	2.2	**4300**	4.10	22	16	400
	10-15 cm	4200	na	20.0	46	<0.25	<0.10	5300	17	44	200	27000	120	1300	300	1.0	**2800**	3.20	21	19	260
	10-15 cm	3200	na	9.5	30	<0.25	<0.10	3900	9	19	97	12000	59	990	180	<0.25	**1100**	1.70	15	12	130
2023401 (Back yard)	0-5 cm	9100	na	**350.0**	180	0.7	<0.10	18000	150	**160**	**860**	57000	**280**	3800	860	2.0	**6600**	3.40	66	33	710
	0-5 cm	7300	na	**77.0**	130	0.7	<0.10	11000	54	**160**	**580**	68000	160	2400	860	2.2	**7000**	6.30	44	31	590
	5-10 cm	12000	na	**69**	310	1	0.50	15000	63	**220**	**970**	99000	**390**	4100	1300	3.7	**11000**	7.8	67	44	**1200**
	5-10 cm	10000	na	**52**	150	0.8	<0.10	9500	49	**150**	**680**	98000	190	3400	1000	3.7	**8700**	7.5	41	37	780
	10-15 cm	13000	na	**69**	160	0.9	<0.10	13000	47	**120**	**630**	72000	**230**	5100	900	2.4	**7600**	6.6	53	40	650
	10-15 cm	14000	na	32	160	0.8	<0.10	13000	31	**91**	**470**	55000	160	4800	640	0.9	**5700**	6	50	37	470
2023501 (Front yard)	0-5 cm	9000	na	**35.0**	180	0.7	0.30	29000	33	**120**	**530**	49000	**310**	1100	850	2.1	**6200**	7.30	100	32	670
	0-5 cm	8500	na	**37.0**	180	0.8	<0.10	28000	40	**150**	**660**	69000	**370**	1100	1000	2.6	**8500**	7.50	85	35	**810**
	5-10 cm	11000	na	**67.0**	210	1	<0.10	30000	57	**200**	**1000**	90000	**400**	1000	1200	3.4	**14000**	8.60	95	39	**1100**
	5-10 cm	12000	na	**53.0**	200	1	<0.10	29000	45	**180**	**840**	93000	**370**	1000	1000	3.7	**13000**	8.40	100	41	**1000**
	10-15 cm	12000	na	**48.0**	200	0.9	<0.10	33000	36	**130**	**1000**	60000	**300**	1000	960	1.7	**12000**	7.10	100	36	**830**
	10-15 cm	9500	na	**48.0**	190	0.8	<0.10	29000	27	**140**	**980**	62000	**350**	8400	1100	2.3	**11000**	6.00	110	32	**840**

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Site / Location	Soil Depth	Al	Sb	As	Ba	Be	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	Sr	V	Zn
2023502 (Back yard)	0-5 cm	9800	na	22.0	240	0.7	0.70	17000	28	**70**	**450**	38000	**460**	3900	510	1.7	**5000**	5.20	90	29	720
	0-5 cm	9700	na	21.0	220	0.6	0.60	15000	26	**65**	**400**	37000	**400**	3700	470	1.9	**4400**	4.90	81	28	680
	5-10 cm	11000	na	19.0	240	0.7	0.30	17000	27	**68**	**430**	37000	**410**	3900	490	1.8	**4700**	5.20	90	30	660
	5-10 cm	9900	na	20.0	200	0.6	0.40	16000	25	**64**	**390**	34000	**380**	3600	450	1.0	**4300**	4.60	82	28	600
	10-15 cm	10000	na	20.0	230	0.7	0.60	25000	28	**69**	**390**	40000	**380**	4800	510	1.5	**4400**	6.80	94	30	620
	10-15 cm	12000	na	17.0	210	0.7	<0.10	39000	26	**54**	300	35000	**310**	6700	540	1.0	**3400**	3.50	110	31	480
2023601 (Rodney St ball diamond)	0-5 cm	5100	na	**29.0**	72	<0.25	<0.10	10000	20	**140**	**560**	43000	110	2700	440	1.4	**7700**	6.20	42	25	400
	0-5 cm	5300	na	**29.0**	71	<0.25	<0.10	10000	20	**130**	**540**	39000	110	2700	450	1.1	**6400**	5.40	46	25	390
	5-10 cm	5000	na	**33.0**	72	<0.25	<0.10	13000	21	**150**	**630**	49000	110	3600	460	1.3	**8600**	6.20	52	27	420
	5-10 cm	5500	na	**32.0**	74	<0.25	<0.10	14000	21	**140**	**640**	42000	110	3800	460	1.1	**7500**	6.50	62	25	430
	10-15 cm	5500	na	**33.0**	75	<0.25	<0.10	16000	22	**130**	**610**	42000	100	4500	410	1.7	**7400**	6.70	74	26	400
	10-15 cm	6100	na	**35.0**	74	<0.25	<0.10	20000	21	**130**	**600**	41000	99	5600	430	1.3	**7300**	7.00	97	27	370
2023701 (Front yard)	0-5 cm	10000	na	16.0	110	0.6	<0.10	20000	23	**71**	290	29000	160	7200	480	<0.25	**3900**	3.90	54	30	370
	0-5 cm	10000	na	16.0	120	0.7	<0.10	23000	23	**85**	**340**	31000	170	8200	530	1.0	**4200**	4.60	61	30	420
	5-10 cm	12000	na	22.0	130	0.7	<0.10	23000	25	**85**	**340**	32000	200	7500	510	1.2	**4500**	4.30	64	32	430
	5-10 cm	9700	na	23.0	120	0.6	<0.10	25000	23	**96**	**400**	34000	200	7500	530	1.6	**5600**	4.70	68	30	440
	10-15 cm	10000	na	**73.0**	160	0.8	<0.10	22000	42	**210**	**1000**	77000	**350**	6600	980	3.0	**14000**	8.30	68	34	**930**
	10-15 cm	10000	na	**56.0**	150	0.7	<0.10	23000	29	**160**	**780**	48000	**310**	6500	720	2.5	**11000**	8.80	81	31	690
2023702 (Back yard)	0-5 cm	9000	na	13.0	110	0.7	<0.10	23000	18	**53**	230	23000	180	7400	400	0.9	**2600**	5.20	120	29	320
	0-5 cm	7300	na	11.0	90	<0.25	<0.10	18000	14	48	190	25000	130	6200	370	0.8	**2700**	2.90	73	26	270
	5-10 cm	7900	na	12.0	100	0.6	<0.10	24000	17	45	190	24000	200	7800	400	0.8	**2600**	2.20	120	27	280
	5-10 cm	9000	na	15.0	110	0.7	<0.10	27000	16	45	210	25000	130	8000	440	1.1	**2500**	2.70	100	29	310
	10-15 cm	8100	na	12.0	120	0.6	0.30	27000	15	39	180	23000	**280**	8000	380	<0.25	**2300**	2.30	140	27	280
	10-15 cm	9200	na	14.0	120	0.7	0.30	26000	16	**53**	230	25000	200	7200	430	1.0	**2700**	2.70	98	30	340
2023801 (Front yard)	0-5 cm	18000	na	12.0	120	0.9	0.70	9900	27	47	150	25000	91	6000	390	1.0	**1800**	2.30	37	40	190
	0-5 cm	20000	na	**130.0**	120	0.9	0.60	7900	27	43	130	24000	83	5000	360	0.8	**1600**	2.10	36	41	180
	5-10 cm	21000	na	**100.0**	120	0.9	0.40	7100	26	29	89	25000	50	5900	410	<0.25	**1000**	1.50	29	43	140
	5-10 cm	22000	na	**82.0**	130	0.9	0.70	5500	28	19	61	26000	39	5600	400	<0.25	**600**	1.10	27	45	110
	10-15 cm	22000	na	**110.0**	130	0.9	0.50	6100	27	25	90	27000	46	5900	400	<0.25	**1000**	1.30	29	45	130
	10-15 cm	21000	na	**130.0**	130	0.9	<0.10	6200	27	24	93	27000	43	6000	400	0.8	**1100**	1.20	28	45	130

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Site / Location	Soil Depth	Al	Sb	As	Ba	Be	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	Sr	V	Zn
2023802 (Back yard)	0-5 cm	16000	na	16.0	190	0.9	0.90	14000	26	**79**	**320**	30000	**320**	5800	480	1.2	**4300**	3.80	51	36	520
	0-5 cm	17000	na	18.0	200	0.9	0.70	13000	30	**83**	**340**	32000	**300**	5700	480	1.3	**4600**	5.30	55	39	530
	5-10 cm	19000	na	15.0	200	1	0.40	12000	30	**75**	**310**	33000	**280**	6300	520	1.0	**4200**	3.20	44	43	470
	5-10 cm	18000	na	20.0	210	0.9	0.50	13000	28	**84**	**460**	34000	**300**	6300	550	0.6	**4700**	0.30	48	41	540
	10-15 cm	15000	na	**32.0**	230	1	0.30	18000	27	**110**	**530**	41000	**410**	6200	580	1.7	**7500**	0.30	66	37	690
	10-15 cm	13000	na	**42.0**	270	1.1	0.50	23000	37	**140**	**740**	49000	**550**	5700	640	2.1	**11000**	0.40	110	35	**940**
2023901 (Back yard)	0-5 cm	12000	na	6.5	80	0.6	<0.10	24000	18	46	120	18000	36	9200	460	<0.25	**1100**	<0.1	42	30	110
	0-5 cm	12000	na	10.0	84	0.6	<0.10	21000	17	47	170	20000	38	7700	510	<0.25	**1400**	<0.1	39	30	130
	5-10 cm	19000	na	7.7	110	0.9	0.70	24000	24	29	88	23000	27	1200	460	<0.25	**780**	<0.1	56	40	97
	5-10 cm	20000	na	11.0	120	0.9	0.50	22000	26	40	130	25000	35	1200	540	<0.25	**1200**	<0.1	49	42	110
	10-15 cm	18000	na	11.0	110	0.9	0.40	30000	42	39	150	24000	39	1300	480	0.8	**1500**	<0.1	60	39	110
	10-15 cm	20000	na	11.0	120	1	0.30	17000	29	**64**	240	29000	48	9800	540	<0.25	**2300**	<0.1	43	44	140
2024101 (Back yard)	0-5 cm	11000	na	13	120	0.6	<0.10	14000	22	**70**	250	21000	140	5500	360	0.9	**3000**	4.2	43	26	310
	0-5 cm	13000	na	11	130	0.7	1.00	15000	25	**70**	260	23000	150	6200	410	<0.25	**3100**	3.1	43	30	300
	5-10 cm	14000	na	14	140	0.8	0.40	20000	26	**64**	270	27000	160	9200	420	0.9	**3200**	3.7	47	34	350
	5-10 cm	12000	na	14	130	0.7	<0.10	21000	23	**61**	260	24000	130	8200	390	<0.25	**3500**	3.2	45	30	260
	10-15 cm	12000	na	34	180	0.8	0.30	19000	28	**87**	**450**	43000	**280**	6900	640	1.3	**5900**	3.9	57	33	520
	10-15 cm	14000	na	19	160	0.8	0.30	28000	25	**60**	**330**	31000	140	1100	480	<0.25	**3600**	3	60	36	370
	15-20 cm	8900	na	**27**	120	0.6	<0.10	17000	24	**80**	**490**	37000	160	5600	550	0.9	**6100**	5.2	62	33	380
	15-20 cm	9200	na	**38**	260	0.6	<0.10	16000	26	**97**	**670**	38000	**210**	5500	520	1.6	**7800**	5.2	58	33	450
2024201 (Side yard)	0-5 cm	13000	na	**29.0**	190	1	0.50	30000	38	**84**	**400**	34000	**420**	9200	620	1.4	**5000**	4.40	89	33	540
	0-5 cm	13000	na	**28.0**	180	1	0.50	32000	36	**90**	**410**	35000	**330**	9800	620	1.3	**5300**	4.20	85	33	540
	5-10 cm	10000	na	**27.0**	200	0.8	<0.10	28000	31	**110**	**530**	38000	**440**	7800	590	1.3	**8200**	5.30	74	27	610
	5-10 cm	12000	na	**29.0**	200	0.9	<0.10	30000	34	**96**	**450**	38000	**440**	8700	620	1.1	**7600**	5.80	81	30	540
	10-15 cm	12000	na	**29.0**	190	0.9	<0.10	32000	26	**96**	**450**	39000	**330**	8100	630	1.2	**8600**	5.00	77	28	610
	10-15 cm	18000	na	20.0	200	1.2	<0.10	33000	29	**55**	250	31000	**230**	1100	600	<0.25	**3800**	3.50	84	37	380
	15-20 cm	19000	na	18.0	200	**1.4**	0.40	31000	26	45	220	31000	**340**	8300	550	<0.25	**3500**	3.40	100	35	370
	15-20 cm	18000	na	18.0	190	1.2	<0.10	37000	35	**54**	250	33000	**300**	1100	620	<0.25	**3200**	2.60	90	35	360

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Site / Location	Soil Depth	Al	Sb	As	Ba	Be	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	Sr	V	Zn
2024601 (Back yard)	0-5 cm	12000	na	17.0	390	0.8	2.20	24000	36	38	370	31000	650	6500	450	1.3	2300	3.80	130	33	1200
	0-5 cm	12000	na	21.0	420	0.8	2.40	25000	41	41	380	31000	740	6900	480	0.9	2200	4.50	140	34	1300
	5-10 cm	11000	na	17.0	400	0.8	2.30	26000	36	36	360	30000	600	6900	410	1.3	1900	3.60	140	32	1100
	5-10 cm	11000	na	19.0	360	0.9	2.20	22000	34	42	430	38000	650	6400	430	1.6	3000	4.80	130	33	1200
	10-15 cm	12000	na	19.0	580	0.8	2.60	29000	44	35	430	40000	890	8700	500	1.8	2000	4.40	170	36	1300
	10-15 cm	10000	na	20.0	340	0.9	2.20	22000	34	38	410	34000	670	6500	400	1.5	2400	4.50	150	33	1000
	15-20 cm	14000	na	19.0	400	1.2	2.60	22000	38	35	420	38000	700	6400	470	1.1	2200	4.20	180	42	960
	15-20 cm	10000	na	23.0	380	0.9	2.60	21000	34	48	410	46000	870	5700	460	1.9	3200	5.10	160	33	1100
2292316 (Front yard)	0-5 cm	15000	<0.4	9.0	154	1.1	0.75	27600	23	22	104	22500	213	1300	461	4.5	401	<0.3	113	33	183
2292317 (Front yard)	0-5 cm	17000	<0.4	10.5	150	1	1.41	17700	32	48	235	22500	236	7740	459	3.7	1680	<0.3	63	34	394
	5-10 cm	19100	<0.4	9.7	159	1.2	1.37	17100	32	48	246	24700	206	7850	463	3.7	1670	<0.3	64	39	368
	10-20 cm	25100	<0.4	10.5	201	1.5	1.29	17500	37	43	337	30100	188	9150	420	3.7	1570	<0.3	75	50	379
2292318 (Back yard)	0-5 cm	19300	<0.4	10.0	184	1.2	1.36	18100	32	35	164	26800	192	6820	446	3.9	1320	<0.3	71	38	314
	5-10 cm	21100	<0.4	9.4	179	1.2	1.17	22900	32	31	139	27300	154	7290	437	3.7	1080	<0.3	70	41	263
	10-20 cm	20200	<0.4	12.2	196	1.2	1.51	16600	33	36	174	28900	184	6940	412	3.7	1670	<0.3	69	40	318
2292319 (Front yard)	0-5 cm	17500	<0.4	10.9	145	1.1	1.34	19400	28	49	231	24700	201	8220	520	3.7	1850	<0.3	58	35	291
	5-10 cm	19800	<0.4	11.4	153	1.1	1.37	23100	29	50	236	26800	203	9020	555	3.8	1920	<0.3	65	39	287
	10-20 cm	18700	<0.4	15.1	174	1.2	1.56	22500	28	57	301	28300	249	8880	538	4.0	2700	0.50	75	37	327
2292320 (Back yard)	0-5 cm	20800	<0.4	17.3	288	1.6	2.17	19400	35	51	333	29400	377	7320	466	3.9	2300	<0.3	114	43	593
	5-10 cm	19900	<0.4	17.8	293	1.5	2.13	20300	34	52	391	30700	369	7220	497	4.2	2670	0.30	116	40	610
	10-20 cm	19600	<0.4	21.2	267	1.5	2.10	24500	31	46	390	30700	336	7400	486	3.9	2790	0.60	125	39	498
2292321 (Front yard)	0-5 cm	16000	<0.4	8.8	118	0.9	1.39	14000	26	61	242	20300	159	6300	397	3.5	1580	<0.3	41	35	248
	5-10 cm	16700	<0.4	6.7	106	0.9	0.95	11200	22	40	156	20000	124	5570	351	3.2	1200	<0.3	35	34	198
	10-20 cm	18000	<0.4	6.7	119	1.1	0.99	18800	23	32	124	20400	170	6710	361	3.6	976	<0.3	50	36	224
2292322 (Back yard)	0-5 cm	17700	<0.4	8.6	165	1.1	1.32	20600	25	33	152	22700	231	9120	382	3.8	1210	<0.3	407	35	339
	5-10 cm	19500	<0.4	7.8	172	1.7	1.23	21200	27	33	154	26400	314	9310	438	3.8	1130	<0.3	87	37	404
	10-20 cm	19200	<0.4	8.4	231	1.2	0.97	34700	27	26	119	24600	589	1300	484	4.3	974	<0.3	97	36	588

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2292323 (Front yard)	0-5 cm	19900	<0.4	9.7	169	1.2	1.35	15300	30	38	211	26000	165	7020	578	3.6	1380	<0.3	59	40	298
	0-5 cm	19100	<0.4	9.5	158	1.2	1.09	13100	28	37	196	24100	143	6560	484	3.8	1280	<0.3	50	38	268
	0-5 cm	21000	<0.4	8.0	155	1.2	1.05	13500	30	35	179	26700	155	6700	588	3.9	1310	<0.3	53	42	299
	5-10 cm	19300	<0.4	9.9	158	1.1	1.19	12900	27	39	217	25500	156	6360	494	3.6	1520	<0.3	51	37	272
	5-10 cm	19800	<0.4	10.8	162	1.2	1.13	12300	30	39	219	27100	161	6410	517	3.7	1550	<0.3	48	38	265
	5-10 cm	21900	<0.4	8.6	168	1.2	1.09	12500	30	39	218	27300	167	6410	517	3.6	1480	<0.3	52	42	263
	10-20 cm	17800	<0.4	14.1	153	1.2	1.50	15900	26	38	245	29200	144	6420	633	3.5	1850	<0.3	56	34	396
	10-20 cm	20600	<0.4	11.9	150	1.2	1.13	14100	29	40	236	27000	146	6600	559	3.4	1790	<0.3	49	40	261
	10-20 cm	19800	<0.4	11.8	152	1.2	1.20	14000	27	39	223	29800	137	6340	697	3.6	1840	<0.3	51	38	314
2292324 (Back yard)	0-5 cm	13600	<0.4	13.2	185	1.1	2.07	14500	23	42	210	22900	256	5770	541	3.7	1820	0.30	78	31	394
	0-5 cm	15100	<0.4	1.3	188	1	1.45	13600	25	39	203	23600	224	5230	464	3.7	1920	<0.3	69	33	364
	0-5 cm	15700	<0.4	14.4	194	1.2	1.84	15000	27	44	227	25500	263	5610	438	3.8	2060	0.50	76	35	384
	5-10 cm	15700	<0.4	15.5	216	1.2	2.12	17000	27	48	246	27800	276	6630	611	4.0	2340	0.60	89	33	446
	5-10 cm	15900	0.4	13.8	211	1.1	1.57	15700	27	43	223	25900	266	6080	503	3.9	2230	0.50	77	35	418
	5-10 cm	15900	<0.4	18.4	219	1.3	2.37	17000	28	50	266	26800	344	6000	492	3.9	2650	0.60	87	35	424
	10-20 cm	15600	1.0	20.0	266	1.8	1.78	21900	26	42	241	24400	263	6220	504	4.1	2320	0.30	170	34	433
	10-20 cm	16700	<0.4	17.8	207	1.2	1.58	19500	28	41	230	26400	260	6700	494	3.8	2360	0.70	92	35	412
	10-20 cm	15500	<0.4	18.0	224	1.2	1.72	22000	28	43	245	28000	237	6570	431	4.2	2400	0.80	109	35	391
2292325 (Front yard)	0-5 cm	13500	<0.4	7.2	99	0.7	0.81	18900	20	25	120	16600	95	7760	321	4.0	894	<0.3	59	30	158
	5-10 cm	13500	<0.4	7.9	94	0.7	0.83	13500	19	32	143	15800	104	5380	278	3.6	1070	<0.3	46	29	163
	10-20 cm	13100	<0.4	9.8	92	0.7	0.87	12000	20	38	184	17800	88	4780	293	3.7	1700	<0.3	40	27	183
2292326 (Back yard)	0-5 cm	11300	<0.4	10.4	111	0.6	1.18	16000	23	28	160	16000	148	6380	269	3.8	939	<0.3	43	24	294
	5-10 cm	10400	<0.4	10.0	109	0.6	1.11	13500	19	28	158	16100	143	5740	246	3.6	1130	<0.3	43	23	315
	10-20 cm	11900	<0.4	11.2	141	0.7	0.94	15000	20	31	242	16700	173	5890	244	3.6	1170	<0.3	49	24	329
2292327 (Front yard)	0-5 cm	28200	<0.4	12.1	218	1.3	1.63	20700	37	72	303	28900	210	1050	453	4.8	3340	<0.3	64	52	351
	5-10 cm	29500	<0.4	15.0	234	1.3	2.03	27100	42	96	438	32100	216	1220	497	4.7	4710	0.45	69	54	432
	10-20 cm*	20200	0.6	21.2	183	1	0.90	47625	31	76	416	33100	175	1867	590	3.2	5785	2.58	83	39	331
2292328 (Back yard)	0-5 cm	26900	<0.4	12.2	192	1.3	1.76	30200	33	61	266	32700	212	1170	724	4.8	2820	<0.3	73	48	331
	5-10 cm	26100	<0.4	9.4	161	1.2	1.28	35500	31	48	207	29700	133	1560	604	5.0	2280	<0.3	70	46	255
	10-20 cm	21500	<0.4	9.5	141	1	0.77	51700	27	32	155	26100	94	2120	550	5.0	1820	<0.3	81	39	175
2292329 (Front yard)	0-5 cm	24600	<0.4	13.7	203	1.3	1.85	21200	36	71	292	28800	261	9280	596	4.8	3310	<0.3	73	52	430
	5-10 cm	25200	<0.4	14	205	1	1.90	21200	36	82	344	30500	228	9270	596	5	4120	1	75	53	406
	10-20 cm*	25025	0.5	17.5	208	1.2	1.21	17725	35	71	328	30450	199	8538	709	2.7	3593	1.41	65	51	344

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2292330 (Back yard)	0-5 cm	25900	<0.4	8.6	162	1.3	0.90	17900	32	35	136	27800	109	8120	459	4.4	1440	<0.3	69	48	213
	5-10 cm	31100	<0.4	8.2	182	1.5	0.87	32700	36	35	128	32700	93	1000	538	4.6	1310	<0.3	81	55	192
	10-20 cm*	20400	0.5	13.8	143	1.1	0.79	15425	28	42	196	25700	99	5823	444	2.6	2088	1.18	71	43	218
2292331 (Side yard)	0-5 cm	23800	<0.4	13.0	119	1.1	1.04	24400	34	67	243	30000	169	9020	774	4.7	2880	<0.3	36	49	270
	5-10 cm	26600	<0.4	12	138	1	0.90	49500	34	49	188	29900	337	9310	744	5	2100	<0.3	43	51	245
	10-20 cm	25700	<0.4	9.0	109	1.1	0.58	80100	28	23	63	25200	73	8080	682	5.3	524	0.34	49	46	111
2292332 (Back yard)	0-5 cm	19400	<0.4	8.7	122	0.8	0.83	14600	28	27	107	19300	91	7490	386	4.0	1130	<0.3	49	35	194
	5-10 cm*	19400	0.5	10.9	124	0.8	0.74	15325	28	29	127	18375	94	7445	355	2.4	1248	0.60	53	36	212
	10-20 cm*	16050	0.5	13.8	121	0.8	0.77	33750	24	32	156	17275	123	1742	323	3.0	1615	0.70	83	31	243
2292333 (Front yard)	0-5 cm	18700	<0.4	13.1	141	0.9	1.44	12600	32	70	305	26500	261	6760	619	4.1	3320	1.00	42	40	412
	5-10 cm*	16700	0.6	16.4	131	0.8	0.99	12200	29	65	318	25800	246	6555	605	2.5	3650	1.48	37	38	380
	10-20 cm*	16275	0.5	18.2	135	0.8	0.91	13075	27	58	315	26175	234	6495	612	2.3	3693	2.35	38	36	341
2292334 (Back yard)	0-5 cm*	16475	0.4	11.0	104	0.7	0.69	9180	24	35	149	19875	90	4635	315	2.2	1620	0.65	36	34	215
	5-10 cm	18500	<0.4	9	101	1	0.78	9600	23	32	132	21700	78	4950	340	4	1530	<0.3	36	37	183
	10-20 cm*	17125	0	14	112	1	0.66	13125	24	32	173	20775	89	5543	326	2	1703	1	46	35	214
2292335 (Front yard)	0-5 cm	21300	<0.4	8.6	125	0.9	0.99	12100	32	64	208	22700	179	6160	427	4.1	2140	<0.3	44	42	267
	5-10 cm	21100	<0.4	8.4	123	0.9	0.98	13300	30	76	237	23600	172	6640	439	4.1	2600	<0.3	43	42	273
	10-20 cm*	20550	0.5	22.3	121	1	0.85	10363	32	100	441	29425	164	5645	500	2.5	5913	3.15	42	41	307
2292336 (Back yard)	0-5 cm*	13100	0.4	11.3	102	0.6	1.27	13400	43	65	239	21775	170	5835	416	2.6	2598	2.23	45	34	349
	5-10 cm	15800	<0.4	13	104	1	1.55	12000	31	89	376	36400	171	5660	482	4	4670	3	43	36	430
	10-20 cm*	13600	0.3	6.2	75	0.5	0.50	30010	19	21	90	21475	55	4580	325	1.9	1165	0.56	30	36	142
2292337 (Front yard)	0-5 cm	21200	<0.4	18.6	157	1.1	1.60	11900	34	112	384	28800	208	6850	615	4.0	4680	1.56	39	48	401
	5-10 cm	18000	<0.4	14	116	1	1.10	9130	27	57	242	26900	101	6260	636	4	3090	0	28	42	227
	10-20 cm*	17650	0.4	14.4	104	0.8	0.58	9745	27	48	231	25125	86	5995	569	2.2	3133	1.58	28	39	204
2292338 (Back yard)	0-5 cm	22700	<0.4	12.5	186	1.1	1.26	11100	33	55	249	28200	153	5770	555	4.1	2820	0.30	53	47	328
	5-10 cm	18500	<0.4	12	138	1	0.92	9200	26	40	178	21700	95	4780	485	4	2000	<0.3	43	37	230
	10-20 cm*	18800	0.4	14.9	168	1	0.67	11058	28	45	226	23625	112	5068	434	2.3	2698	0.92	49	40	250

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2292339 (Front yard)	0-5 cm	24700	<0.4	16.5	339	1.2	1.46	14000	36	99	345	26700	425	7590	474	0.8	3390	0.40	56	52	694
	0-5 cm	22800	0.5	21.4	348	1.2	1.68	14400	36	152	497	25700	431	7610	464	0.9	4730	1.51	58	50	717
	0-5 cm	23900	<0.4	17	356	1	1.38	12600	34	114	380	26000	465	7240	490	1	3650	1	53	50	661
	5-10 cm	29900	1	31	326	1	2.07	16000	43	222	694	32800	352	8870	494	1	7000	2	66	59	697
	5-10 cm	28000	1	27	250	1	1.55	15900	38	188	616	30300	251	8740	493	1	6330	1	62	56	523
	5-10 cm	28600	<0.4	24.4	305	1.4	1.63	14500	42	179	561	29500	312	8070	491	0.8	5610	0.88	63	55	553
	10-20 cm*	28675	1.1	30.2	243	1.4	1.28	17650	42	162	654	32275	224	8638	464	2.0	7540	3.58	68	54	600
	10-20 cm*	25800	1.2	36.9	269	1.3	1.19	17225	45	214	871	35200	282	8295	500	2.1	9025	5.83	69	52	914
	10-20 cm	28075	1.1	31.2	243	1.4	1.24	19500	45	174	718	33825	249	8930	486	2.1	8363	3.65	69	53	605
2292340 (Back yard)	0-5 cm	15700	<0.4	26.5	143	0.9	1.12	15000	25	31	165	20700	184	5840	466	0.4	1230	<0.3	62	37	273
	0-5 cm*	13475	0.3	12.4	97	0.7	0.58	10048	21	24	116	19175	76	4945	516	1.2	935	0.65	41	32	211
	0-5 cm*	11700	0.4	11.6	101	0.7	0.60	12250	19	26	148	18425	113	4860	441	1.3	857	0.69	46	30	231
	5-10 cm*	15075	0.5	32.5	120	0.8	0.78	15525	24	32	175	21150	184	5828	473	1.3	1480	0.58	52	36	227
	5-10 cm*	11375	<0.47	7.8	62	0.5	0.34	8195	15	16	63	17700	39	4250	568	1.0	486	0.45	28	27	104
	5-10 cm*	11750	0	11	79	1	0.54	12500	17	23	110	18325	78	4883	519	1	865	1	39	29	169
	10-20 cm*	13825	0.4	27.5	128	0.9	0.69	14325	23	32	180	19725	156	5323	426	1.3	1665	0.50	61	34	235
	10-20 cm*	12950	0.4	17.5	115	0.8	0.69	12925	20	31	167	19525	96	4938	476	1.2	1425	0.60	56	32	220
	10-20 cm*	11375	0.4	15.8	117	0.7	0.70	14000	19	35	221	19050	152	4745	428	1.0	1680	0.63	53	30	261
2292341 (Front yard)	0-5 cm	25600	<0.4	23.2	235	1.7	2.45	19400	38	66	320	26900	244	8540	489	5.4	2970	6.30	77	53	422
	5-10 cm	28700	<0.4	16	205	2	1.52	29600	37	49	208	31500	153	1280	613	6	2060	0	77	56	294
	10-20 cm*	24500	0.6	44.3	227	1.4	2.42	24575	38	100	566	36400	321	9285	777	2.9	6733	2.65	77	48	546
2292342 (Back yard)	0-5 cm	26100	<0.4	31.8	261	1.6	2.37	17700	40	64	372	25700	283	7300	401	5.1	3110	1.20	90	54	434
	5-10 cm	23500	<0.4	44	253	2	2.83	18100	39	69	392	25200	315	7290	390	5	3710	1	92	51	479
	10-20 cm*	22850	0.8	47.6	287	1.4	1.97	19275	38	67	433	27400	367	6773	281	2.6	4570	1.68	102	46	525
2292343 (Front yard)	0-5 cm	17900	<0.4	18.8	282	1.4	2.16	27100	37	107	469	29900	622	1030	589	6.3	5230	2.40	92	44	618
	5-10 cm	16700	<0.4	32.1	288	1.5	2.44	32000	35	116	621	34600	596	1040	704	6.5	7740	<0.3	109	36	638
	10-20 cm*	18700	0.8	25.3	277	1.4	1.30	32400	33	60	423	30600	511	7990	635	2.7	5670	1.84	123	37	472
2292344 (Back yard)	0-5 cm	23300	<0.4	13.5	188	1.4	1.44	16700	33	43	220	24900	159	6880	432	5.5	2080	0.50	80	48	325
	5-10 cm	23400	<0.4	14.1	188	1.4	1.47	16300	33	47	236	25900	176	6900	431	5.3	2330	<0.3	80	48	331
	10-20 cm	25100	<0.4	17.0	200	1.5	1.58	18000	36	50	265	26900	177	7410	434	5.3	2580	<0.3	87	51	334
2292345 (Front yard)	0-5 cm	20200	<0.4	14.5	179	1.4	1.59	30800	32	58	288	27900	179	1200	612	5.7	2770	0.40	82	43	387
	5-10 cm	24200	<0.4	21	209	2	1.86	30600	36	74	406	36400	185	1250	985	6	4380	1	79	47	438
	10-20 cm*	24325	1	22	270	2	2.04	38000	35	52	311	48400	211	1142	1648	3	3620	2	112	44	699
2292346 (Front yard)	0-5 cm	17000	9.2	6.3	160	1.1	1.83	34400	32	40	142	21600	169	1530	819	6.2	999	<0.3	117	42	402

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Site / Location	Soil Depth	Al	Sb	As	Ba	Be	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	Sr	V	Zn
	5-10 cm	18900	9.3	8.0	177	**1.3**	2.45	36200	32	47	166	26100	**217**	1370	1540	6.0	**1240**	<0.3	139	44	610
2292347 (Front yard)	0-5 cm	17700	6.9	10.8	152	1	1.55	24600	33	**55**	272	25900	196	9980	489	5.7	**2650**	<0.3	76	41	374
	5-10 cm	19500	8	14	170	1	1.74	23300	33	**64**	**314**	28000	**260**	9790	479	6	**3070**	<0.3	78	43	395
	10-20 cm*	18550	3	16	163	1	1.55	24075	31	**53**	274	26550	184	9155	475	3	**2655**	1	73	39	333
2292348 (Back yard)	0-5 cm	23100	7.2	11.0	194	1.2	2.90	24500	48	**66**	**318**	27200	**241**	1260	457	5.8	**2620**	<0.3	69	49	536
	5-10 cm	26700	7.7	14.9	210	**1.4**	3.31	22000	48	**84**	**389**	30900	**267**	1100	480	5.7	**3680**	<0.3	65	53	631
	10-20 cm*	24700	2.9	16.8	189	**1.3**	2.14	26650	40	**55**	300	30375	164	1157	445	3.3	**2963**	1.35	75	48	405
2292349 (Back yard)	0-5 cm*	16200	1.9	7.1	156	0.8	1.22	22050	25	24	134	20925	134	7238	409	3.0	**859**	0.65	106	32275	
	5-10 cm	21900	8	8	201	1	1.40	23300	33	33	178	25700	189	7800	456	5	**1110**	<0.3	136	40	351
	10-20 cm*	21200	3	12	312	1	1.82	30500	34	44	**345**	28450	**270**	8108	437	3	**1960**	1	179	39	509
2292350 (Front yard)	0-5 cm*	17375	1.3	6.2	96	0.7	0.77	7375	25	25	89	19750	87	4893	430	2.5	**832**	0.63	28	36	154
	5-10 cm*	16750	1.3	5.6	89	0.7	0.71	6853	23	25	89	19450	77	4525	428	2.4	**811**	0.58	25	35	133
	10-20 cm*	17325	1.0	8.6	98	0.7	0.84	7020	24	36	148	22075	92	4890	474	2.3	**1465**	0.80	25	36	162
2292351 (Back yard)	0-5 cm*	18250	1.9	9.6	157	1	0.97	14525	31	31	124	23000	167	8130	446	2.9	**1285**	0.68	57	40	232
	5-10 cm*	21250	2	10	162	1	0.98	14800	32	33	134	25775	198	8368	478	3	**1328**	1	63	42	234
	10-20 cm*	21450	2.2	10.0	162	1	0.85	16375	30	32	126	26150	196	8383	476	3.0	**1275**	0.68	65	42	215
2292352 (Back yard)	0-5 cm	19300	0.8	12.7	128	0.8	1.25	14000	38	**64**	**455**	25100	164	6360	591	1.1	**2300**	<0.3	45	44	343
	5-10 cm	19500	0.8	14.4	123	0.9	1.13	13200	29	**69**	**569**	25800	122	6310	624	0.8	**2570**	0.90	44	44	316
	10-20 cm	21600	<0.4	13.2	120	0.9	0.98	11900	33	**54**	**516**	26700	100	6360	612	0.8	**2040**	<0.3	45	47	284
2292353 (Front yard)	0-5 cm	10400	3.2	13.5	166	0.5	2.33	66300	30	**77**	299	29400	**562**	3190	478	2.3	**2590**	0.70	104	27	721
2292354 (Front yard)	0-5 cm	18900	0.7	12.1	137	0.8	1.01	10800	31	**118**	**342**	26000	123	6180	553	0.9	**3900**	1.50	54	46	290
	5-10 cm	22600	<0.4	13.0	131	1	0.93	8720	29	**92**	**303**	27300	86	6200	537	0.7	**3190**	<0.3	56	50	225
	10-20 cm	14300	<0.4	7.2	64	0.5	0.40	3550	21	32	120	21000	30	3470	564	0.2	**1420**	<0.3	24	36	131
2292355 (Front yard)	0-5 cm	13500	<0.4	8.3	61	0.4	0.52	6690	17	**51**	148	21900	63	3300	328	0.5	**2150**	<0.3	22	33	164
	5-10 cm	15400	<0.4	5.4	48	0.4	0.36	4910	17	30	85	17100	34	2980	269	0.5	**974**	<0.3	16	34	92
	10-20 cm	15200	1.7	**43.0**	162	1	2.04	15800	32	**167**	**792**	59700	**333**	6200	627	2.0	**12000**	6.10	56	43	743
2292356 (Back yard)	0-5 cm	16100	0.4	12.7	176	0.8	1.15	10200	29	46	193	22600	166	3750	319	0.9	**2070**	0.40	54	38	350
	5-10 cm	19700	1.0	18.8	290	**1.4**	1.87	9100	34	**60**	284	28800	**282**	3730	343	1.7	**3100**	0.40	101	44	542
	10-20 cm	23300	5.3	**38.6**	569	**2.4**	2.30	15100	53	**87**	**619**	42600	**540**	4440	477	2.8	**6300**	2.20	219	55	**923**
2292357 (Front yard)	0-5 cm	14100	1.1	**25.5**	212	0.7	1.77	26400	47	**143**	**581**	34800	**327**	1080	577	1.5	**6770**	4.30	59	39	467
	5-10 cm	12600	1.1	**36.7**	161	0.7	2.13	30900	35	**163**	**775**	49000	**295**	1040	646	1.7	**10600**	5.80	63	38	568
	10-20 cm	15500	2.3	**33.9**	259	0.9	2.21	32000	34	**111**	**751**	41700	**329**	9680	665	1.2	**9300**	4.50	86	40	**886**

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Site / Location	Soil Depth	Al	Sb	As	Ba	Be	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	Sr	V	Zn
2292358 (Back yard)	0-5 cm	16300	1.0	24.1	178	1	1.47	12900	28	**83**	**407**	38800	**212**	5820	472	1.0	**5300**	3.60	59	49	565
	0-5 cm	16200	1.2	**26.1**	206	0.9	1.73	13300	28	**87**	**437**	40600	**257**	5710	496	0.9	**6010**	3.80	63	48	654
	0-5 cm	15100	0.5	20.4	152	0.7	1.19	12400	25	**73**	**349**	30100	176	5430	407	0.8	**4550**	1.30	50	40	406
	5-10 cm	18500	1.8	**35.3**	212	1.2	1.77	16500	31	**78**	**460**	49400	221	6300	519	1.3	**5470**	2.40	79	56	754
	5-10 cm	15800	1.5	**31.3**	191	1.2	1.72	16000	26	**67**	**393**	58100	195	5550	553	1.5	**4740**	1.10	89	62	**944**
	5-10 cm	17500	0.7	**29.8**	192	0.9	1.33	15400	31	**84**	**457**	36800	**249**	6280	482	0.7	**6250**	0.80	60	44	511
	10-20 cm	17100	1.3	**27.7**	224	1.1	1.38	17800	26	**57**	**366**	43900	**206**	6000	464	1.0	**4110**	1.20	78	52	637
	10-20 cm	16800	0.9	**27.3**	175	1	1.28	17200	30	**63**	**355**	39100	168	5840	448	0.9	**4390**	1.50	74	48	572
	10-20 cm	18000	0.5	**30.7**	197	0.9	1.41	17600	33	**78**	**455**	37100	**237**	6470	455	0.8	**5820**	0.80	67	44	529
2292359 (Front yard)	0-5 cm	18200	<0.4	3.6	95	0.6	0.25	14600	22	13	31	19000	23	6570	422	0.3	162	<0.3	48	42	74
	5-10 cm	18800	<0.4	4.0	95	0.6	0.29	13300	32	12	29	20100	22	6100	472	0.3	117	<0.3	46	43	73
	10-20 cm	19600	<0.4	5.6	108	0.7	0.34	20900	24	18	68	23600	47	9150	495	0.5	**632**	<0.3	62	45	101
2292360 (Back yard)	0-5 cm	20800	<0.4	7.7	169	0.8	0.62	27100	25	25	116	25700	117	9670	518	0.5	**1000**	<0.3	67	44	175
	5-10 cm	32800	<0.4	11.3	224	**1.3**	0.62	38900	35	35	152	42800	117	1480	722	0.7	**1550**	<0.3	90	63	238
	10-20 cm	32500	0.7	23.4	377	**1.4**	1.18	25600	43	**77**	**390**	48500	**292**	1250	599	1.2	**5210**	0.70	86	67	491
2292361 (Front yard)	0-5 cm	20300	<0.4	5.6	121	0.7	0.42	20500	24	21	73	21300	37	9660	478	0.6	**528**	<0.3	73	44	111
	5-10 cm	23400	<0.4	6.8	148	0.8	0.45	31700	28	28	118	27100	64	1450	571	0.8	**1190**	<0.3	82	49	166
	10-20 cm	28400	<0.4	10.3	199	1.1	0.63	38800	34	**56**	231	32700	99	1690	541	1.1	**2540**	<0.3	90	58	200
2292362 (Back yard)	0-5 cm	24400	<0.4	7.0	159	0.9	0.38	26400	28	24	98	26400	85	1140	415	0.5	**954**	<0.3	65	50	155
	5-10 cm	35800	<0.4	9.9	242	**1.4**	0.47	34500	40	31	131	39600	111	1530	620	0.8	**1300**	<0.3	88	68	197
	10-20 cm	34900	<0.4	9.3	232	**1.4**	0.40	38100	37	31	150	36900	106	1490	561	0.7	**1320**	<0.3	95	66	197
2292363 (Front yard)	0-5 cm	15300	<0.4	3.7	102	0.5	0.42	13700	20	11	41	16800	19	5770	432	0.4	161	<0.3	51	34	80
	5-10 cm	21400	<0.4	5.7	158	0.7	0.49	19100	27	17	67	22900	39	9390	518	0.7	**454**	<0.3	77	46	113
	10-20 cm	29600	<0.4	7.5	203	1.1	0.56	34600	36	28	132	30600	78	1690	593	0.8	**1120**	<0.3	119	58	147
2292364 (Back yard)	0-5 cm	28000	0.5	9.8	214	1.1	0.72	29100	34	32	176	32100	154	1220	481	0.6	**1350**	<0.3	80	55	241
	5-10 cm	32000	<0.4	10.2	227	**1.3**	0.47	37600	35	31	146	35600	136	1490	519	0.6	**1530**	<0.3	91	62	209
	10-20 cm	31800	<0.4	11.9	272	**1.3**	0.56	39200	36	46	217	37000	**254**	1560	557	0.8	**2120**	<0.3	101	63	251
2292365 (Back yard)	0-5 cm	16000	5.3	**33.2**	447	**1.5**	5.08	33000	45	**175**	**720**	43400	**1130**	8140	819	2.2	**6930**	8.70	129	48	**1590**
	5-10 cm	20000	6.0	**47.7**	557	**2.2**	4.19	43500	47	**177**	**977**	72100	**1290**	7700	954	2.9	**12100**	6.30	192	46	**1440**
	10-20 cm	33100	<0.4	**32.3**	579	**4.6**	4.35	93400	50	**88**	**917**	47600	**877**	7390	1440	6.7	**8680**	1.30	393	33	**1390**
2292366 (Front yard)	0-5 cm	19400	<0.4	23.4	160	0.7	1.69	16400	40	**115**	**462**	43200	**213**	8830	669	5.2	**6870**	3.40	56	42	587
	5-10 cm	22200	<0.4	**41.2**	193	0.8	2.41	15200	48	**147**	**671**	57400	**245**	8460	804	5.9	**10500**	6.60	51	43	**836**
	10-20 cm	24400	<0.4	24.2	171	0.9	1.57	15100	40	**78**	**384**	39500	157	8620	654	4.8	**5380**	3.00	52	48	463

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2292367 (Back yard)	0-5 cm	22400	<0.4	**26.7**	190	0.9	1.78	13800	37	**81**	**357**	35500	**207**	6480	671	4.4	**4240**	1.80	68	46	441
	5-10 cm	21200	<0.4	**30.0**	178	0.9	1.60	10500	36	**68**	**336**	36300	168	5950	606	4.4	**4610**	1.00	61	43	392
	10-20 cm	22700	<0.4	**33.4**	198	1	1.68	13200	38	**58**	**319**	36600	189	6420	582	4.7	**4180**	0.70	75	45	381
2292368 (Front yard)	0-5 cm	17300	<0.4	8.3	109	0.6	0.83	15200	25	32	153	20300	66	7120	409	4.0	**1470**	<0.3	54	36	190
	5-10 cm	17200	<0.4	9.0	123	0.6	0.99	16800	26	46	212	22200	100	7400	453	4.1	**1860**	<0.3	55	36	259
	10-20 cm	19100	<0.4	**30.3**	184	0.8	2.17	20900	38	**129**	745	46500	**252**	9270	680	5.4	**9120**	5.10	64	39	745
2292369 (Back yard)	0-5 cm	16200	<0.4	18.2	162	0.7	1.43	21900	31	**73**	**370**	30300	**213**	7350	520	4.7	**4310**	1.70	70	33	405
	5-10 cm	17200	<0.4	24.0	163	0.7	1.47	22600	33	**83**	**434**	34000	**205**	7990	538	4.7	**5430**	1.80	69	33	414
	10-20 cm	18500	<0.4	23.8	177	0.8	1.46	26900	31	**72**	**433**	33900	**206**	8070	542	4.7	**5100**	1.80	78	35	420
2292370 (Front yard)	0-5 cm	17700	<0.4	8.9	128	0.6	1.01	18700	27	42	176	24800	115	8290	505	4.4	**1660**	<0.3	59	35	239
	5-10 cm	17100	<0.4	10.8	131	0.6	1.09	16000	31	50	204	26500	135	7600	550	4.5	**2060**	<0.3	43	34	261
	10-20 cm	22500	<0.4	17.1	165	0.8	1.30	20100	39	**56**	276	36600	153	9070	644	4.7	**3190**	0.30	50	40	321
2292371 (Back yard)	0-5 cm	16300	<0.4	16.1	198	0.9	1.51	18200	28	**58**	**335**	27600	**206**	5990	548	4.5	**3030**	1.20	69	32	413
	5-10 cm	17100	<0.4	20.5	233	0.8	1.56	19800	31	**66**	**411**	31900	**224**	6500	588	4.6	**3750**	0.30	74	34	461
	10-20 cm	17400	<0.4	20.5	231	0.8	1.50	20900	34	**61**	**454**	31900	**235**	6270	619	4.8	**3600**	0.30	82	33	465
2292372 (Front yard)	0-5 cm	21700	<0.4	12.7	136	0.7	2.16	17700	35	**51**	214	27900	117	8140	444	4.8	**2130**	<0.3	60	41	274
	0-5 cm	20600	<0.4	14.8	154	0.7	2.86	19200	33	**55**	231	27800	145	8810	463	4.8	**2280**	0.50	64	39	328
	0-5 cm	20500	<0.4	12.9	129	0.6	2.32	16000	31	49	207	28300	109	7340	411	4.5	**2270**	<0.3	55	37	263
	5-10 cm	25700	<0.4	12.5	145	0.8	1.95	12500	35	50	202	30700	105	7140	451	4.4	**2130**	<0.3	51	45	253
	5-10 cm	22500	<0.4	13.9	148	0.8	3.94	14600	36	**61**	230	30200	139	7900	480	4.3	**2380**	<0.3	54	42	337
	5-10 cm	23100	<0.4	13.2	140	0.7	1.84	13000	33	47	201	29900	106	6370	440	4.2	**2270**	<0.3	51	41	258
	10-20 cm	23100	<0.4	16.4	150	0.8	2.19	16600	36	**62**	284	32800	136	7460	501	4.6	**3360**	<0.3	57	41	357
	10-20 cm	21600	<0.4	23.9	160	0.8	3.40	19600	38	**90**	**423**	41300	177	8880	567	5.3	**5360**	2.20	64	39	482
	10-20 cm	21000	<0.4	20.6	176	0.7	2.08	17900	43	**73**	**339**	36100	180	7010	485	4.9	**4180**	1.30	59	37	377
2292373 (Back yard)	0-5 cm	19200	<0.4	10.7	149	0.7	1.30	13200	30	46	197	26900	188	5190	408	4.3	**2060**	<0.3	48	38	287
	0-5 cm	18200	<0.4	9.1	154	0.8	1.17	17900	29	43	184	26100	162	6070	415	4.3	**1890**	<0.3	53	37	301
	0-5 cm	18300	<0.4	10.2	155	0.9	1.25	14700	31	47	204	26600	183	5890	426	4.2	**1960**	<0.3	53	38	345
	5-10 cm	20300	<0.4	11.7	174	1	1.27	11400	32	48	218	28400	**207**	5990	440	4.1	**2200**	<0.3	53	40	390
	5-10 cm	19200	<0.4	10.2	152	0.8	1.07	11900	30	40	169	25300	158	5720	418	3.9	**1660**	<0.3	46	39	289
	5-10 cm	20100	<0.4	11.5	171	0.9	1.23	10900	32	49	204	28300	188	5930	435	4.1	**2170**	<0.3	51	40	355
	10-20 cm	23500	<0.4	18.8	311	1.2	1.67	19200	41	**65**	**376**	41300	**438**	7440	534	5.0	**4260**	<0.3	78	43	559
	10-20 cm	19300	<0.4	13.8	203	1	1.28	26700	37	48	262	31300	**236**	7250	483	4.9	**2780**	<0.3	75	39	385
	10-20 cm	21900	<0.4	23.5	301	1.2	1.89	21400	49	**69**	**443**	38400	**453**	7830	516	5.1	**4470**	0.90	86	44	615

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Site / Location	Soil Depth	Al	Sb	As	Ba	Be	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	Sr	V	Zn
2292374 (Front yard)	0-5 cm	18400	<0.4	10.2	137	0.8	2.07	20700	31	55	206	30000	133	1030	485	4.6	2170	<0.3	59	38	323
	5-10 cm	20800	<0.4	16.9	165	1	2.83	24000	37	73	300	40000	171	1170	679	5.0	3440	1.10	68	43	441
	10-20 cm	21200	<0.4	17.0	169	1.1	2.38	27400	36	56	276	40800	156	1260	623	5.0	3190	<0.3	78	43	397
2292375 (Back yard)	0-5 cm	22700	<0.4	6.7	157	0.9	1.64	12800	32	42	153	27000	138	7080	522	4.1	1350	<0.3	48	44	278
	5-10 cm	24400	<0.4	7.1	161	1	1.69	10700	35	44	163	29600	130	6880	568	3.8	1440	<0.3	44	47	276
	10-20 cm	22800	<0.4	4.7	145	0.9	1.36	9950	33	33	121	28800	97	6540	602	3.9	1100	<0.3	38	45	225
2292376 (Front yard)	0-5 cm	20000	<0.4	13.1	174	0.9	1.44	22000	36	68	319	32500	329	1010	470	4.7	3340	0.90	69	41	403
	5-10 cm	25400	<0.4	17.4	212	1.1	1.63	24200	42	73	375	40000	188	1100	537	4.9	4050	1.10	77	49	452
	10-20 cm	30800	1.6	23.1	267	1.7	1.16	29300	40	52	303	42200	199	1300	533	1.2	2950	0.40	100	64	362
2292377 (Back yard)	0-5 cm	17200	1.5	14.6	190	1.1	1.56	45500	28	55	275	25900	174	2330	470	1.3	2300	1.00	111	40	380
2292378 (Back yard)	0-5 cm	16300	2.9	16.4	178	1	1.67	18200	26	50	252	22800	393	7550	343	0.7	2300	0.70	100	39	381
	5-10 cm	15300	3.7	17.1	186	1	1.69	19300	26	52	328	23800	490	7700	363	0.7	2290	0.90	96	38	395
	10-20 cm	17500	8.7	42.9	307	1.3	3.17	22000	40	117	694	43300	1140	8850	563	1.6	6670	3.80	130	48	938
2292379 (Front yard)	0-5 cm	11800	1.5	14.6	135	0.7	1.40	41400	33	130	640	22600	205	2140	514	1.3	3870	1.60	89	36	281
	5-10 cm	14800	2.2	31.6	176	1	2.51	31200	38	220	1120	33400	331	1600	613	1.8	6320	4.30	82	47	501
	10-20 cm	23400	1.5	28.4	226	1.4	2.30	31700	43	146	816	46600	246	1460	682	1.6	6060	1.00	93	54	470
2292380 (Back yard)	0-5 cm	29200	2.0	9.9	221	1.5	0.96	21300	42	41	163	35200	298	1290	605	1.0	1070	<0.3	149	61	256
	5-10 cm	30600	1.2	9.0	208	1.5	0.78	26100	46	36	132	34900	172	1510	612	1.1	869	<0.3	147	63	225
	10-20 cm	32800	<0.4	9.3	206	1.6	0.69	24400	47	34	113	36200	131	1330	616	0.9	768	<0.3	131	67	204
2292381 (Back yard)	0-5 cm	14900	2.8	10.9	297	0.8	2.84	54400	35	47	204	25500	594	2350	502	1.8	962	0.30	149	31	635
2292382 (Front yard)	0-5 cm	11900	<0.4	9.1	115	0.8	0.81	26700	21	31	162	22800	103	1090	476	5.1	1060	<0.3	79	25	179
2292382 (Back yard)	0-5 cm	21000	0.4	7.3	197	1.3	0.92	26300	32	28	113	30300	140	1040	594	4.6	666	<0.3	99	37	208
	5-10 cm	23800	0.5	5.7	219	1.5	0.89	26800	33	31	120	31900	160	1070	602	4.5	703	<0.3	100	41	224
	10-20 cm	24200	0.4	6.7	192	1.4	0.80	25600	34	28	108	30400	158	1020	541	4.7	620	<0.3	108	43	200
2292384 (Front yard)	0-5 cm	11200	<0.4	6.2	90	0.7	0.54	23000	18	15	73	16200	114	8530	322	4.1	563	<0.3	73	23	136
	5-10 cm	11100	<0.4	8.4	96	0.7	0.57	24900	17	16	78	17300	105	8640	328	4.2	626	<0.3	84	23	141
	10-20 cm	10800	<0.4	6.8	97	0.7	0.55	24700	17	17	74	16700	106	8120	314	4.1	702	<0.3	92	23	132
2292385 (Back yard)	0-5 cm	18000	<0.4	5.3	135	1	0.58	21800	25	20	69	22500	95	9030	448	4.0	502	<0.3	90	34	151
	5-10 cm	20800	0.4	5.9	144	1.1	0.57	23900	28	21	71	26400	103	9820	508	4.2	511	<0.3	94	37	146
	10-20 cm	21700	1.0	6.1	163	1.2	0.64	24000	31	23	84	27100	119	9830	477	4.4	576	<0.3	110	40	170
2292386 (Front yard)	0-5 cm	11400	<0.4	5.2	81	0.7	0.47	22800	17	13	52	15000	71	9150	275	3.9	400	<0.3	81	23	114
	5-10 cm	12000	<0.4	5.5	86	0.7	0.48	24800	17	14	54	15700	76	9460	317	4.1	465	<0.3	90	24	115
	10-20 cm	9710	<0.4	6.4	86	0.6	0.43	26200	15	13	48	16400	66	1030	371	4.0	435	<0.3	102	21	100

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Site / Location	Soil Depth	Al	Sb	As	Ba	Be	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	Sr	V	Zn
2292387 (Back yard)	0-5 cm	13600	<0.4	5.7	107	0.8	0.57	23100	21	17	64	19700	82	7780	378	4.1	**489**	<0.3	97	26	140
	5-10 cm	17700	<0.4	7.1	135	1.1	0.56	25800	28	18	64	22500	89	8850	414	4.0	**454**	<0.3	107	32	137
	10-20 cm	14400	<0.4	5.5	103	0.9	0.46	21500	20	15	50	19600	76	7360	349	3.7	**418**	<0.3	91	29	112
2292388 (Front yard)	0-5 cm	12300	<0.4	5.4	86	0.8	0.51	19900	18	14	53	16100	69	6930	331	3.8	**478**	<0.3	76	24	127
	5-10 cm	12300	<0.4	5.9	88	0.8	0.55	21300	18	15	56	17200	70	7120	321	3.8	**507**	<0.3	82	24	140
	10-20 cm	13100	<0.4	5.5	99	0.8	0.57	23800	19	15	66	17400	76	7030	338	3.9	**523**	<0.3	99	25	139
2292389 (Back yard)	0-5 cm	9470	<0.4	6.4	93	0.8	0.77	24500	15	18	79	18500	102	5300	442	3.8	**851**	<0.3	76	18	203
	5-10 cm	8940	<0.4	7.8	91	0.8	0.75	25500	15	16	75	16900	104	5480	397	3.7	**707**	<0.3	82	17	190
	10-20 cm	10600	<0.4	10.0	138	**1.3**	0.95	41700	17	22	110	20400	151	8030	487	4.4	**1100**	<0.3	138	17	234
2292390 (Front yard)	0-5 cm	10200	<0.4	5.0	79	0.6	0.46	22800	16	12	51	15300	49	6160	352	3.9	**401**	<0.3	71	20	109
	5-10 cm	11100	<0.4	5.7	84	0.7	0.52	22300	18	15	58	17200	59	6860	365	3.7	**527**	<0.3	73	23	130
	10-20 cm	11400	<0.4	6.7	87	0.8	0.53	24500	17	16	61	18300	66	7220	347	3.8	**595**	<0.3	86	23	129
2292391 (Back yard)	0-5 cm	11000	<0.4	7.8	121	1	1.02	28900	18	22	102	20600	174	6470	432	4.0	**1030**	<0.3	96	20	256
	5-10 cm	12100	<0.4	9.2	132	1	1.02	32000	18	22	108	20300	171	7050	478	4.4	**986**	<0.3	113	21	260
	10-20 cm	10300	<0.4	8.9	126	0.9	0.98	30000	18	26	112	21800	**221**	6600	470	4.5	**1280**	<0.3	104	20	263
2292392 (Front yard)	0-5 cm	7180	<0.4	14.6	155	0.7	1.85	43700	22	43	214	24200	**278**	2020	485	5.5	**1910**	1.30	149	17	442
	5-10 cm	7450	0.4	19.8	161	0.7	2.56	47300	26	**60**	299	35700	**282**	1930	644	5.8	**3010**	1.70	149	18	488
	10-20 cm	8780	<0.4	17.6	201	0.8	1.70	32400	20	34	215	25700	**304**	7830	511	4.7	**2190**	0.60	132	16	422
2292393 (Back yard)	0-5 cm	10400	<0.4	6.9	98	0.6	0.86	12900	18	26	111	22200	117	4550	491	3.8	**1070**	<0.3	41	25	285
	5-10 cm	8820	0.9	16.1	145	0.6	1.79	19700	24	48	242	32800	**230**	5480	596	4.4	**2440**	1.60	61	23	577
	10-20 cm	7140	1.0	23.8	268	0.6	2.32	27800	24	42	293	33100	**383**	6240	574	4.7	**2420**	1.20	88	15	910
2292394 (Front yard)	0-5 cm	10300	<0.4	14.2	120	0.7	1.51	18800	25	46	217	32700	196	7040	537	4.6	**2420**	1.20	63	24	370
	5-10 cm	13100	0.4	19.2	152	0.9	2.02	20700	31	**54**	284	37000	**253**	7500	662	4.7	**2890**	1.90	67	26	467
	10-20 cm	11500	<0.4	17.2	148	0.8	1.64	23300	25	43	260	33200	**229**	6910	563	4.5	**2820**	0.70	64	25	442
2292395 (Back yard)	0-5 cm	13400	<0.4	6.1	101	0.7	0.64	13900	18	18	70	18600	84	4830	491	3.8	**589**	<0.3	46	27	169
	5-10 cm	11300	<0.4	13.3	136	0.7	1.17	19700	22	35	164	25500	166	5810	611	4.2	**1400**	0.40	62	27	329
	10-20 cm	8770	0.7	19.2	188	0.7	1.62	27500	25	39	229	33700	**253**	6940	513	4.8	**2120**	0.70	75	22	491

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Site / Location	Soil Depth	Al	Sb	As	Ba	Be	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	Sr	V	Zn
2292396 (Front yard)	0-5 cm	18300	0.5	8.4	137	1	1.07	13500	28	32	141	28500	299	6470	493	4.1	1270	<0.3	43	37	269
	0-5 cm	18900	0.6	9.5	153	1	1.22	16600	29	36	162	29500	311	7390	514	4.4	1510	<0.3	47	39	298
	0-5 cm	19400	0.8	10.3	143	1	1.13	15400	30	36	164	32600	332	7010	551	4.3	1700	<0.3	49	38	295
	5-10 cm	22700	0.8	8.6	156	1.1	1.06	11900	32	34	145	31400	283	6890	529	3.9	1420	<0.3	41	43	266
	5-10 cm	26800	1.0	6.7	179	1.3	0.99	12200	35	30	127	32600	261	7580	591	4.0	1130	<0.3	103	49	240
	5-10 cm	21200	1.0	10.0	148	1	1.10	14600	31	37	178	33400	349	7220	581	4.3	1690	<0.3	46	40	295
	10-20 cm	15600	0.8	19.9	168	1	2.10	20800	36	65	312	47000	666	7570	657	5.0	3690	1.90	54	31	534
	10-20 cm	15500	1.0	18.9	161	0.9	1.79	28100	32	56	290	43900	462	8560	726	5.1	3260	0.50	63	29	483
	10-20 cm	19300	0.9	17.0	164	1	1.66	21800	35	52	270	42000	580	8060	663	4.8	2910	<0.3	56	35	449
2292397 (Back yard)	0-5 cm	9060	1.7	27.1	236	0.6	2.37	22900	25	46	240	31500	448	5120	524	4.4	2630	1.30	94	22	726
	0-5 cm	7640	0.8	25.0	183	0.6	2.56	24100	24	44	239	29200	393	5800	563	4.5	2260	1.90	93	20	556
	0-5 cm	10000	1.8	30.1	235	0.7	2.48	24500	29	47	262	29500	510	5630	572	4.7	2380	3.00	107	23	683
	5-10 cm	7060	1.5	37.2	238	0.6	2.48	31900	28	47	293	35400	464	6370	554	4.9	3010	1.10	116	17	752
	5-10 cm	7490	1.6	41.9	284	0.7	2.95	36000	27	46	325	32400	549	6560	580	5.0	2840	3.20	141	15	719
	5-10 cm	7320	2.9	38.9	248	0.7	2.61	31800	27	49	309	35800	583	6410	568	5.0	3230	2.40	119	17	685
	10-20 cm	6240	1.2	29.4	217	0.6	2.02	37500	23	34	250	27800	408	6450	484	4.7	2220	0.80	146	14	570
	10-20 cm	6070	1.2	27.3	225	0.5	2.05	35300	22	33	237	28200	405	6370	485	4.7	2140	1.90	131	14	589
	10-20 cm	5930	1.5	29.3	244	0.6	2.01	35900	25	37	249	31600	454	6520	480	4.7	2550	1.80	136	14	709
2292398 (Front yard)	0-5 cm*	15550	0.4	9.2	126	0.8	0.96	15100	24	33	158	28600	197	6805	481	4.1	1575	<0.3	54	33	260
	5-10 cm*	16300	0.5	12.4	135	0.9	1.12	16350	26	37	186	32100	223	6735	497	4.2	1955	0.33	54	32	294
	10-20 cm*	16850	0.3	14.0	149	0.9	1.19	24000	28	39	242	34350	246	8580	526	4.5	2165	0.38	69	33	385
2292399 (Back yard)	0-5 cm*	10045	<0.4	13.5	92	0.5	1.00	13450	19	24	117	19550	137	3910	331	3.5	1130	0.28	55	23	235
	5-10 cm*	10435	<0.4	16.7	100	0.5	1.09	16300	20	24	124	20550	143	4330	343	3.6	1200	<0.3	60	22	235
	10-20 cm*	7935	<0.4	24.1	148	0.5	1.44	25300	22	28	177	24250	199	5310	401	3.9	1660	0.66	99	17	311
2292400 (Front yard)	0-5 cm	17800	0.5	14.5	116	1	1.23	10100	27	36	177	28000	135	4170	581	3.7	1880	0.40	56	35	259
	5-10 cm	19200	0.4	17.7	134	1	1.33	11400	29	38	193	31200	156	4430	626	4.0	2160	0.80	67	36	286
	10-20 cm	14300	0.9	22.9	149	0.8	1.49	16800	27	45	246	35500	208	4420	528	4.2	3190	2.00	95	28	351
2292401 (Back yard)	0-5 cm	17400	1.0	10.3	131	0.9	1.05	13200	26	30	137	29900	182	4930	680	4.4	1380	<0.3	59	35	299
	5-10 cm	16700	1.0	10.1	127	0.9	1.03	12400	22	27	134	29800	190	5120	689	4.2	1360	<0.3	54	27	283
	10-20 cm	11700	0.6	11.5	165	0.8	1.09	21700	22	27	164	29600	230	5420	527	4.2	1650	0.40	93	27	362
2292402 (Front yard)	0-5 cm	20800	1.0	8.0	169	1	0.96	28300	31	24	99	29200	279	8640	536	4.7	818	<0.3	85	39	253
	5-10 cm	29000	0.8	4.9	198	1.3	0.79	27800	35	22	75	32300	215	9840	627	4.5	552	<0.3	88	50	202
	10-20 cm	29500	<0.4	6.2	174	1.3	0.76	24800	35	27	92	34400	114	9260	660	4.4	742	<0.3	79	51	166

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2292403 (Back yard)	0-5 cm	18100	0.8	4.1	99	0.8	0.83	19200	22	14	57	19800	76	8870	587	4.2	191	<0.3	83	34	171
	5-10 cm	17500	<0.4	3.0	92	0.8	0.71	21400	22	13	47	19100	59	8860	575	4.1	170	<0.3	93	33	139
	10-20 cm	17600	0.7	2.6	89	0.7	0.56	23700	21	12	44	18500	48	8560	539	4.2	137	<0.3	114	33	118
2292404 (Front yard)	0-5 cm	23100	<0.4	4.3	140	1.1	0.60	46500	28	21	64	24900	68	1530	544	4.9	**295**	<0.3	109	40	148
	5-10 cm	23700	<0.4	6.1	145	1.2	0.78	47800	29	28	87	27600	98	1590	571	4.7	**509**	<0.3	119	42	182
	10-20 cm	14300	<0.4	10.6	109	0.8	1.10	28900	24	36	136	23800	148	9250	497	4.4	**952**	<0.3	90	30	260
2292405 (Back yard)	0-5 cm	16800	0.5	3.3	97	0.7	0.50	12000	20	11	41	19500	65	5700	387	3.5	170	<0.3	51	32	114
	5-10 cm	16300	0.4	6.5	126	0.7	0.75	19400	21	16	60	22300	121	7000	433	3.8	**432**	<0.3	65	31	195
	10-20 cm	6830	1.9	19.6	264	0.5	2.15	28800	23	32	219	31900	**417**	6190	550	4.3	**1660**	1.10	95	16	635
2292406 (Front yard)	0-5 cm	18300	0.5	3.1	93	0.8	0.52	12400	21	14	55	18200	53	5590	366	3.5	**313**	<0.3	69	35	102
	5-10 cm	22500	<0.4	5.9	132	1	0.69	21200	26	21	108	21400	80	7820	403	3.9	**639**	<0.3	106	42	140
	10-20 cm	24600	0.7	7.6	155	1.2	0.98	30200	30	23	122	25100	111	1000	448	4.5	**721**	<0.3	162	44	201
2292407 (Back yard)	0-5 cm	16300	<0.4	13.9	233	1.1	1.64	21000	30	32	187	29400	**258**	6520	536	4.2	**1400**	<0.3	115	33	465
	5-10 cm	16100	2.1	22.2	373	**1.3**	2.41	27800	40	48	**325**	43200	**394**	7130	740	5.2	**2580**	1.00	163	32	743
	10-20 cm	16400	3.1	**37.9**	451	**1.4**	3.25	32900	59	52	**392**	49200	**617**	6960	852	5.8	**3070**	1.80	215	30	**1000**
2292408 (Front yard)	0-5 cm	23200	<0.4	5.9	124	1.1	0.84	15900	34	25	95	29000	99	8800	534	4.2	**769**	<0.3	57	45	176
	5-10 cm	26400	<0.4	5.8	136	**1.3**	0.81	16900	37	25	94	30000	96	9470	552	4.1	**710**	<0.3	58	49	169
	10-20 cm	29200	<0.4	4.7	144	**1.3**	0.61	19800	37	20	63	30400	68	1100	561	4.2	**461**	<0.3	55	52	131
2292409 (Back yard)	0-5 cm	19900	<0.4	12.2	173	1	1.62	15400	32	31	203	30300	**285**	6780	514	4.4	**1250**	<0.3	94	40	383
	5-10 cm	23600	0.4	15.6	210	1.2	1.76	15200	37	34	190	36300	**259**	6410	526	4.6	**1630**	<0.3	117	43	402
	10-20 cm	17000	1.3	**29.7**	699	1.1	2.82	23900	43	49	**1620**	47300	**534**	5480	628	5.5	**2800**	2.20	209	30	923
2292410 (Front yard)	0-5 cm	17800	<0.4	5.5	119	0.9	0.81	26100	26	19	95	22200	119	1130	497	4.1	**600**	<0.3	83	35	181
	5-10 cm*	18400	0.4	7.8	132	0.9	0.97	26900	30	18	86	24350	125	1100	578	3.1	**593**	0.51	86	37	207
	10-20 cm*	22850	0.5	11.9	190	1.2	0.93	25350	34	25	133	30375	**201**	1060	605	3.1	**1218**	0.55	136	45	246
2292411 (Back yard)	0-5 cm*	13650	1.8	8.6	99	0.5	1.07	26300	27	14	72	18825	91	1000	500	2.9	**361**	0.38	80	29	189
	5-10 cm*	12950	2	7	101	1.0	1.40	37950	30	13	83	20450	124	1377	562	3	**469**	0	83	28	242
	10-20 cm*	12975	2.3	7.5	130	0.6	1.69	47175	33	16	116	22325	**276**	1727	571	3.9	**618**	0.40	132	28	302
2292412 (Back yard)	0-5 cm	16700	<0.4	7.5	229	1	1.95	27800	30	45	226	23500	**307**	1200	420	4.4	**1540**	<0.3	87	46	493
	5-10 cm	17100	<0.4	8	223	1.0	2.07	29800	28	46	241	24700	**341**	1270	436	4	**1530**	<0.3	89	63	489
	10-20 cm*	15600	2.5	13.0	318	1	2.38	37300	31	50	326	25275	**446**	1477	463	3.7	**2318**	1.25	111	54	637
2292413 (Back yard)	0-5 cm	21600	<0.4	11.0	194	1	1.07	24200	35	49	210	24100	173	1020	463	4.6	**1290**	<0.3	63	41	354
	5-10 cm	25000	<0.4	11	223	1.0	1.18	18700	36	43	208	26900	190	8080	485	4	**1510**	<0.3	62	47	386
	10-20 cm*	23525	1.9	15.7	202	1	1.11	18025	35	43	217	27550	174	7343	540	3.0	**1863**	1.10	58	43	388

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Site / Location	Soil Depth	Al	Sb	As	Ba	Be	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	Sr	V	Zn
2292414 (Back yard)	0-5 cm	20300	1.0	21.8	285	1.2	2.00	21200	35	83	427	31100	254	8500	468	4.2	3540	1.40	92	42	636
	5-10 cm	20700	0.8	20.3	282	1.1	1.92	17900	34	82	426	29900	257	7170	469	4.2	3280	1.40	77	42	638
	10-20 cm*	20150	2.5	22.3	288	1	1.78	16400	36	95	438	31750	280	6850	525	3.1	3893	2.03	70	43	813
2292415 (Front yard)	0-5 cm*	8523	1.2	3.9	82	0.4	0.26	42950	12	7	34	14125	14	6463	595	2.3	48	0.23	81	20	66
	5-10 cm*	11975	1.3	4.3	90	0.5	0.43	32325	18	16	57	16625	31	6193	562	2.2	272	0.38	69	26	97
	10-20 cm	20900	<0.4	5.3	134	1	0.93	21300	30	42	143	22800	89	6650	492	3.9	1000	<0.3	64	42	161
2292416 (Back yard)	0-5 cm	30300	<0.4	10.6	205	1.5	1.28	12900	42	69	265	29500	182	6520	441	3.9	2210	0.70	71	56	274
	5-10 cm	32500	<0.4	11.1	224	1.7	1.03	13700	40	58	251	33100	183	7740	464	3.7	2430	<0.3	68	59	259
	10-20 cm	29200	<0.4	19.9	255	1.6	1.35	18100	41	61	345	37600	260	7660	471	4.1	3930	0.80	87	54	404
2292417 (Front yard)	0-5 cm	19800	<0.4	7.6	133	1	0.85	25600	29	67	246	23500	169	1460	471	4.2	2120	<0.3	143	41	246
2292418 (Back yard)	0-5 cm	19400	1.3	17.5	254	1.3	1.96	24000	40	93	396	32100	308	9760	504	4.7	4030	2.20	95	42	699
	5-10 cm	22400	1.7	18.7	330	1.6	1.77	30800	49	67	328	32600	334	1230	492	5.5	3470	1.20	140	49	825
	10-20 cm	28200	<0.4	13.0	232	1.5	1.12	24600	41	54	254	33800	204	1410	496	4.5	2510	<0.3	90	53	341
2292419 (Front yard)	0-5 cm	15200	<0.4	12.0	167	0.8	1.64	15400	32	134	388	23500	324	6920	492	3.7	3750	2.80	47	37	400
	5-10 cm	16600	0.5	15.6	145	0.9	1.80	13000	31	122	421	25800	256	5940	469	3.7	4320	4.40	43	38	360
	10-20 cm	19500	<0.4	15.0	135	1	1.17	11700	30	74	329	30200	129	6050	588	3.7	4190	1.60	40	40	266
2292420 (Back yard)	0-5 cm	15000	0.5	12.5	148	0.8	2.17	16100	30	103	364	24400	176	6950	480	3.7	2990	2.70	102	32	289
	5-10 cm	15500	<0.4	14.6	132	0.9	2.25	14200	29	93	367	25300	144	6750	531	3.6	3210	2.20	84	32	269
	10-20 cm	16400	<0.4	15.0	157	0.9	1.11	19500	26	141	459	27100	151	7750	472	3.8	3660	1.40	131	32	240
2292421 (Front yard)	0-5 cm	22500	1.1	15.0	178	1.2	1.73	11900	42	151	514	32000	292	7090	738	4.1	5080	2.90	44	46	573
	5-10 cm	26100	<0.4	10.4	161	1.4	1.27	10800	35	79	288	30300	153	7960	838	3.7	2860	0.70	37	47	407
	10-20 cm	26600	0.7	15.2	172	1.4	1.17	15100	38	71	337	33700	176	9650	680	4.4	4210	2.10	42	46	370
2292422 (Back yard)	0-5 cm	16700	<0.4	5.0	103	0.8	0.79	15800	22	29	105	18400	101	7680	344	3.4	963	<0.3	45	33	150
	5-10 cm	17900	<0.4	5.9	111	0.9	0.85	17500	23	31	115	20300	111	8440	378	3.4	1070	<0.3	47	34	157
	10-20 cm	15700	<0.4	7.8	99	0.8	0.79	22900	21	29	120	20100	127	9230	389	3.7	1360	<0.3	59	31	162
2292423 (Front yard)	0-5 cm	19800	3.0	15.1	180	1.3	1.74	19300	36	90	394	32300	201	7010	492	4.4	4400	1.90	76	40	374
	5-10 cm	22100	2.1	13.0	178	1.4	1.25	17800	30	53	268	29700	160	6470	422	3.6	2740	0.90	76	40	277
	10-20 cm	25100	5.8	23.3	276	1.8	1.55	23700	40	63	354	39900	324	7200	465	4.5	4780	<0.3	125	42	408
2292424 (Front yard)	0-5 cm	16200	0.6	12.1	169	1.1	1.28	24200	31	68	301	26300	205	9480	476	4.2	3140	0.70	83	36	377
	5-10 cm	18500	1.3	18.2	207	1.5	1.47	24100	34	77	400	29300	246	9260	474	4.2	4060	1.30	124	38	514
	10-20 cm	18600	1.6	26.7	201	1.3	1.63	25600	34	82	454	33700	223	9650	428	4.4	5580	2.20	117	38	453
2292425 (Back yard)	0-5 cm	19800	<0.4	6.0	161	1.1	1.45	20800	28	44	149	23500	155	8750	482	3.6	1200	<0.3	71	37	257
	5-10 cm	25000	<0.4	5.3	184	1.3	0.99	22400	31	38	125	27600	130	1030	519	3.6	967	<0.3	74	43	221
	10-20 cm	20900	<0.4	7.7	141	1.1	0.88	24000	26	40	163	26800	93	1030	477	3.7	1550	<0.3	61	37	185

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Site / Location	Soil Depth	Al	Sb	As	Ba	Be	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	Sr	V	Zn
2292426 (Front yard)	0-5 cm	20000	<0.4	4.3	123	1	0.70	20700	27	32	106	22000	99	1270	456	3.9	**799**	<0.3	73	41	168
	5-10 cm	20200	<0.4	4.5	119	1.1	0.62	22500	27	30	94	22000	89	1330	478	3.9	**687**	<0.3	66	41	152
	10-20 cm	19800	<0.4	4.3	121	1	0.86	23200	27	27	103	23300	131	1390	554	4.1	**894**	<0.3	57	39	173
2292427 (Front yard)	0-5 cm	19700	<0.4	5.0	119	1	0.80	13900	26	34	143	21300	96	6960	357	3.7	**1120**	<0.3	55	40	196
	5-10 cm	24500	<0.4	6.4	143	1.2	0.86	11900	32	40	163	24700	110	6820	438	3.6	**1320**	<0.3	53	46	226
	10-20 cm	24500	<0.4	6.5	152	1.2	0.82	11900	31	42	185	25400	160	6890	422	3.7	**1680**	<0.3	50	44	219
2292428 (Back yard)	0-5 cm	22100	<0.4	7.9	201	1.2	2.65	14400	32	39	206	25400	154	6480	364	4.0	**1690**	<0.3	83	43	312
	5-10 cm	29100	<0.4	9.6	266	**1.6**	1.60	15800	41	49	256	30100	**206**	7360	431	4.1	**2000**	<0.3	101	51	400
	10-20 cm	29500	<0.4	14.1	330	**1.7**	1.85	13600	41	**56**	276	33000	189	7180	460	4.2	**2830**	<0.3	123	52	401
2292429 (Front yard)	0-5 cm	10300	<0.4	5.3	68	0.6	0.49	11800	17	30	124	16300	95	5630	402	3.4	**1080**	<0.3	34	29	143
	5-10 cm	10600	<0.4	3.4	61	0.6	0.44	9450	16	23	93	14800	73	4620	391	3.1	**719**	<0.3	30	28	105
	10-20 cm	11300	<0.4	8.6	102	0.7	0.77	13900	19	48	217	19700	134	6250	443	3.5	**2010**	0.50	39	30	225
2292430 (Back yard)	0-5 cm	16300	0.6	17.1	242	1.2	2.09	19300	34	**82**	**366**	30000	**623**	7230	500	4.5	**3360**	2.80	87	37	625
	5-10 cm	20600	1.5	**26.9**	352	**1.4**	2.56	21000	39	**91**	**516**	36700	**797**	7470	555	4.7	**5070**	2.80	103	43	742
	10-20 cm	23700	5.7	**28.5**	565	**1.8**	2.27	28900	49	**74**	**522**	37500	**1460**	8130	576	4.7	**4960**	1.40	209	47	**916**
2292431 (Front yard)	0-5 cm	16400	<0.4	16.0	182	1	1.36	20300	31	**79**	**414**	30100	**401**	7940	492	4.1	**3400**	1.60	70	41	639
	5-10 cm	16200	<0.4	19.7	155	1	1.38	19800	29	**84**	**442**	31600	**325**	8180	507	4.3	**4120**	2.50	65	41	533
	10-20 cm	15600	<0.4	21.2	168	1	1.21	19200	26	**62**	**419**	31100	**250**	6540	496	3.9	**3380**	2.00	76	39	403
2292432 (Back yard)	0-5 cm	19800	<0.4	17.3	244	1.2	1.91	16500	37	**74**	**408**	31200	**386**	6450	548	4.4	**3920**	1.20	78	42	592
	5-10 cm	22100	1.4	20.0	274	**1.4**	2.16	15000	39	**84**	**465**	34400	**531**	6190	635	4.3	**4730**	1.90	82	45	632
	10-20 cm	21900	1.1	24.7	292	**1.4**	1.90	16100	36	**75**	**468**	34700	**485**	6060	618	4.1	**4890**	2.20	91	44	571
2292433 (Front yard)	0-5 cm	19400	1.9	10.6	168	1.2	1.54	28400	33	**60**	299	23800	**274**	1230	439	4.6	**2290**	0.80	114	34	494
	0-5 cm	21700	1.7	8.8	174	**1.3**	1.52	23900	38	**60**	278	24000	**257**	9710	449	4.3	**2240**	<0.3	95	37	505
	0-5 cm	23200	3.2	8.9	196	**1.3**	1.69	24300	39	**62**	288	24100	**313**	1030	466	4.4	**2180**	0.30	97	41	605
	5-10 cm	22400	2.1	12.5	198	**1.4**	1.70	28600	41	**78**	**382**	26900	**348**	1260	483	4.7	**2930**	1.30	118	38	598
	5-10 cm	23200	2.4	11.8	203	**1.4**	1.74	24400	39	**81**	**360**	27800	**347**	1080	482	4.5	**3010**	<0.3	97	41	629
	5-10 cm	26200	4.6	15.0	215	**1.5**	2.14	27300	50	**120**	**489**	29800	**518**	1280	564	4.7	**3640**	1.40	104	49	**930**
	10-20 cm	29700	3.0	16.1	248	**1.8**	1.85	27900	44	**89**	**493**	35300	**358**	1220	519	4.6	**4900**	1.00	161	45	705
	10-20 cm	25400	2.9	22.4	231	**1.6**	2.27	27000	43	**132**	**597**	40500	**383**	1190	587	4.9	**6310**	2.00	110	43	**801**
	10-20 cm	28900	4.6	19.6	285	**1.8**	2.20	25400	47	**122**	**564**	38100	**459**	1160	555	4.8	**5430**	1.30	116	49	**839**

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2292434 (Back yard)	0-5 cm	21900	0.8	11.0	164	1.3	1.05	10300	29	65	278	29400	209	4030	482	3.8	2870	1.00	61	38	358
	0-5 cm	21300	0.7	10.4	169	1.2	1.08	10300	27	63	261	28500	194	3910	458	3.7	2700	0.70	62	37	363
	0-5 cm	23300	0.5	10.9	178	1.3	1.12	10400	30	70	283	30300	209	4370	466	3.8	3080	0.70	62	43	365
	5-10 cm	23700	1.4	12.7	192	1.5	1.09	11100	32	66	326	34700	219	4160	547	3.9	3530	1.10	68	39	380
	5-10 cm	23300	0.9	12.6	192	1.4	1.19	11300	30	72	312	34800	253	4270	577	3.7	3480	0.60	69	38	461
	5-10 cm	26300	0.7	15.8	200	1.5	1.28	11700	33	71	329	34300	226	4680	542	3.9	3510	0.80	70	44	391
	10-20 cm	27800	0.6	11.1	258	1.6	0.97	15100	35	46	270	33600	251	5040	521	4.0	2660	<0.3	89	43	355
	10-20 cm	26900	0.4	8.8	194	1.4	0.83	10300	32	44	200	32200	172	4760	520	3.8	2180	<0.3	68	43	301
	10-20 cm	30600	0.6	15.6	321	1.8	1.26	13900	39	59	325	38900	320	5560	505	4.1	3910	0.30	106	50	434
2292435 (Back yard)	0-5 cm	25900	5.1	17.8	258	1.4	2.32	17300	38	84	471	33400	315	6870	549	4.2	3590	1.70	90	48	516
	5-10 cm	29500	1.2	22.5	238	1.6	1.95	17000	41	98	571	38900	473	7190	666	4.4	4880	1.20	93	52	459
	10-20 cm	31700	0.8	23.2	297	1.8	1.73	25000	58	149	1230	41400	261	7720	540	4.3	6390	1.60	149	48	503
2292436 (Back yard)	0-5 cm	13400	<0.4	7.1	125	0.7	1.50	16000	22	29	103	20200	228	7270	543	3.4	809	<0.3	62	27	213
2292437 (Front yard)	0-5 cm*	14100	1.6	7.1	87	0.7	0.77	15750	23	30	134	20800	84	7185	556	2.3	984	0.60	42	34	140
	5-10 cm*	14700	1.6	8.9	91	0.7	0.82	15300	24	33	147	21925	93	7015	621	2.2	1085	0.58	42	34	144
	10-20 cm*	14125	1.5	6.8	79	0.7	0.63	16250	21	21	96	21350	57	6175	625	2.1	690	0.48	42	32	102
2292438 (Back yard)	0-5 cm*	14775	1.5	8.8	90	0.8	0.82	19150	22	28	124	19450	123	6338	512	2.3	1230	0.73	52	31	204
	5-10 cm*	14900	1.9	10.9	121	0.8	0.83	18750	23	29	130	20500	127	6560	519	2.3	1313	0.73	52	33	214
	10-20 cm*	15425	1.9	12.2	135	0.9	0.76	20925	23	30	148	21950	142	7028	509	2.9	1565	0.68	61	34	219
2292439 (Front yard)	0-5 cm	21200	<0.4	10	135	1.0	0.97	13400	29	56	216	25400	106	8380	471	5	2190	2	42	44	216
	5-10 cm	24300	<0.4	10.0	150	1.4	0.89	15900	31	48	187	27700	95	9830	531	5.1	1900	<0.3	42	47	192
	10-20 cm*	25900	0.4	10.4	171	1.3	0.76	28350	34	39	184	29825	79	1180	601	2.8	1683	0.73	65	48	206
2292440 (Back yard)	0-5 cm	16300	<0.4	17.1	185	1.2	1.41	15600	25	40	202	20900	202	6300	401	5.0	1930	0.90	75	35	322
	5-10 cm*	15650	0.5	18.8	191	1	1.26	18075	25	40	219	20200	223	6223	403	2.5	2098	1.04	82	34	338
	10-20 cm*	18700	0.7	27.6	261	1.3	1.53	19625	30	48	233	23775	272	6490	459	2.6	2853	1.75	118	39	408
2292441 (Front yard)	0-5 cm	21900	<0.4	15.2	171	1.4	1.54	23600	33	71	322	23900	144	1030	452	5.8	3050	1.10	70	48	282
	0-5 cm	21200	<0.4	16.5	174	1.4	1.65	24400	35	74	343	24200	151	1060	430	5.7	3240	2.20	73	47	286
	0-5 cm	22100	<0.4	19.2	186	1.4	1.65	24000	33	80	385	24800	151	1020	424	5.6	3950	0.90	71	47	304
	5-10 cm	22800	<0.4	20	182	1.0	1.73	23400	33	84	426	27200	157	1030	467	6	4480	3	74	49	329
	5-10 cm	22300	<0.4	21.0	180	1.4	1.77	23800	34	87	427	28000	201	1010	485	5.6	4580	2.90	70	48	318
	5-10 cm	21100	<0.4	24	172	1.0	2.11	24300	35	110	507	29600	187	1080	472	6	6330	4	69	46	356
	10-20 cm	22700	1	24	182	1.0	0.92	26200	33	78	456	28400	146	9867	472	2	5077	3	77	47	314
	10-20 cm*	19733	0.6	24.4	179	1.1	1.05	25433	30	82	462	27567	170	9583	453	2.5	5440	3.00	71	43	346
	10-20 cm*	21925	0.5	22.8	176	1.2	1.06	24025	32	82	460	28650	148	9103	441	2.8	5328	1.70	72	45	302

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Site / Location	Soil Depth	Al	Sb	As	Ba	Be	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	Sr	V	Zn
2292442 (Back yard)	0-5 cm*	14900	0.5	13.6	122	0.9	1.14	14933	23	36	192	17500	118	6197	289	2.2	**1813**	1.77	61	33	264
	0-5 cm	13700	<0.4	13.0	107	0.9	1.12	13900	20	36	177	16400	100	5790	273	4.7	**1680**	1.10	52	31	230
	0-5 cm	14700	<0.4	12.2	122	1	1.21	14800	22	36	171	17900	102	6150	282	4.8	**1670**	0.90	59	34	231
	5-10 cm*	16200	0.5	16.0	134	1	1.14	15933	24	38	214	18333	136	6500	294	2.1	**2017**	1.63	68	35	271
	5-10 cm*	13775	1	15	118	1.0	0.98	16150	21	38	207	16825	117	6308	271	2	**2045**	1	58	31	263
	5-10 cm	15200	<0.4	14	127	1	1.32	14700	23	45	223	18800	114	6450	301	5	**2300**	2	61	35	245
	10-20 cm*	13400	1	17	143	1	1.11	20567	22	32	205	17633	124	7067	281	2	**1990**	1	88	29	291
	10-20 cm*	10400	0.4	16.4	102	0.7	0.84	18700	18	36	237	15625	91	6108	238	2.3	**2145**	1.14	65	25	258
	10-20 cm*	13800	0.5	21.6	157	0.9	1.34	19950	23	37	233	18075	125	7093	278	2.6	**2198**	1.19	71	29	312
2292443 (Front yard)	0-5 cm	21800	<0.4	16.0	153	**1.3**	1.68	13700	34	**83**	**356**	27200	170	8090	593	5.6	**3670**	1.10	42	49	522
	5-10 cm	20300	<0.4	**29.7**	159	**1.3**	2.71	15300	38	**164**	**709**	37700	**218**	8930	712	5.9	**8900**	5.20	40	49	789
	10-20 cm*	19000	1	21	145	1	0.97	18600	29	**72**	**493**	27367	158	8257	551	2	**5387**	2	43	42	414
2292444 (Back yard)	0-5 cm	19700	<0.4	9.2	135	1.2	0.95	13500	29	32	148	22300	98	7970	483	4.9	**1240**	1.50	49	43	255
	5-10 cm	19800	<0.4	12.1	142	1.2	1.00	16300	29	35	162	23100	97	9250	490	5.1	**1400**	<0.3	51	42	255
	10-20 cm*	14033	0.7	17.6	159	0.9	0.78	20133	26	39	240	21933	**240**	7203	341	2.6	**2287**	0.95	76	36	329
2292445 (Front yard)	0-5 cm	28000	1.2	16.0	245	**1.7**	1.84	19700	154	**56**	**314**	27000	179	9040	447	5.5	**2910**	1.30	93	54	626
	5-10 cm	28600	1.7	18.6	270	**1.8**	2.09	19900	245	**63**	**359**	28300	187	9410	449	5.5	**3390**	0.90	90	55	**827**
	10-20 cm*	26475	1.1	19.1	242	**1.5**	1.42	20525	183	**52**	**323**	27100	167	8980	440	2.8	**3170**	1.59	89	50	673
2292446 (Back yard)	0-5 cm*	15250	0.4	8.2	136	1.2	0.88	17975	29	24	134	19875	120	8393	526	2.8	**1085**	0.63	121	34	339
	5-10 cm*	15300	0.4	7.8	127	**1.3**	0.87	19650	28	24	120	19925	110	8833	529	2.7	**1038**	0.58	135	34	319
	10-20 cm*	19800	1	16	243	**3**	1.14	20900	35	31	195	22067	**224**	8070	462	4	**1527**	1	273	45	451
2292447 (Front yard)	0-5 cm	20400	9.4	7.6	216	1.1	1.20	20000	32	43	179	25200	**524**	9330	539	4.5	**1620**	<0.3	63	41	311
	5-10 cm	21200	8.8	7.5	176	1.1	1.05	18300	31	40	157	25800	**360**	8730	460	4.2	**1430**	<0.3	56	41	246
	10-20 cm	17800	8.0	7.9	153	1	1.44	28000	27	35	153	26200	**278**	1110	479	4.4	**1570**	<0.3	65	35	222
2292448 (Back yard)	0-5 cm	26200	**23.6**	9.7	409	**1.4**	1.60	27600	40	43	225	32700	**1340**	9600	505	4.5	**2190**	<0.3	102	48	583
	5-10 cm	26300	**19.1**	8.5	329	**1.4**	1.45	23100	38	42	210	31900	**1010**	8650	463	4.5	**2000**	<0.3	96	48	490
	10-20 cm	25500	**18.7**	12.0	366	**1.4**	1.83	25600	41	49	**312**	35600	**1130**	9520	512	4.6	**2650**	<0.3	101	47	645
2292449 (Front yard)	0-5 cm*	16175	2.6	15.0	147	0.9	1.38	25775	30	43	224	30500	177	1100	532	3.5	**1975**	1.39	86	36	335
	5-10 cm*	19075	2.7	14.6	154	1	1.30	28500	31	38	188	32025	155	1190	550	3.4	**1790**	0.90	77	40	297
	10-20 cm*	19075	2.6	13.4	139	1	1.04	24850	29	32	159	31375	126	1025	524	3.4	**1610**	0.83	64	39	260
2292450 (Back yard)	0-5 cm*	9820	2.2	15.6	160	0.6	1.39	22350	23	28	175	23625	**227**	6805	417	2.6	**1470**	1.23	115	28	353
	5-10 cm	9610	6.9	16.0	138	0.7	1.35	21500	24	28	151	24100	**207**	6600	442	5.0	**1310**	0.55	105	29	316
	10-20 cm*	9593	2.4	17.8	149	0.6	1.26	23275	21	28	180	24400	**206**	6700	413	2.6	**1548**	0.87	120	26	319

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Site / Location	Soil Depth	Al	Sb	As	Ba	Be	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	Sr	V	Zn
2292451 (Front yard)	0-5 cm*	13750	1.7	7.1	87	0.7	1.00	14400	22	21	106	20150	95	5813	360	2.4	**909**	0.60	58	30	172
	5-10 cm*	13725	1.7	7.6	84	0.7	0.98	14525	22	22	112	20125	105	5760	351	2.3	**895**	0.60	58	30	166
	10-20 cm*	12375	1.9	13.3	104	0.6	1.43	14450	23	38	211	27350	162	4838	430	2.8	**1933**	1.13	64	27	295
2292452 (Front yard)	0-5 cm	19900	5.6	7.8	168	1	0.98	17400	32	23	100	22300	167	9180	428	5.0	**667**	<0.3	70	42	255
	5-10 cm*	19975	1.7	7.9	152	0.9	1.00	11750	28	21	93	22950	158	6735	427	2.4	**585**	0.58	58	41	235
	10-20 cm*	20000	1.8	6.9	152	0.9	0.96	10148	28	20	88	23725	162	6135	409	2.2	**607**	0.50	47	40	229
2292453 (Back yard)	0-5 cm*	12900	2.0	10.8	186	0.6	1.19	10875	23	18	130	18450	**309**	3833	445	2.6	**606**	0.58	76	34	343
	5-10 cm*	12775	1.4	9.1	182	0.6	1.10	10528	21	18	115	18850	**266**	3640	482	2.1	**601**	0.63	74	33	302
	10-20 cm*	12400	1.6	9.6	168	0.6	0.93	10650	20	18	160	18600	**242**	3463	433	2.6	**650**	0.55	72	32	287
2292454 (Front yard)	0-5 cm*	12725	1.4	10.8	111	0.6	1.01	16825	21	28	136	19575	166	7175	402	2.7	**1078**	0.73	66	29	249
	5-10 cm*	13750	1.3	9.0	90	0.5	0.86	11975	19	27	118	18875	129	5863	361	2.5	**982**	0.68	47	29	200
	10-20 cm*	14200	2.0	18.0	152	0.8	1.21	23225	25	45	227	30425	199	1082	571	3.6	**2350**	1.89	88	30	324
2292455 (Back yard)	0-5 cm*	12225	1.0	5.8	75	0.4	0.72	6853	18	17	73	14625	**208**	2713	236	2.3	**438**	0.60	41	26	237
	5-10 cm	13600	3.0	3.4	64	0.5	0.64	5040	17	16	57	16300	103	2480	239	2.9	**380**	<0.3	33	28	158
	10-20 cm	14200	2.9	4.9	77	0.6	0.66	5660	18	17	83	16700	106	2610	221	2.9	**558**	<0.3	45	27	148
2292456 (Front yard)	0-5 cm	11200	4.9	19.1	215	0.9	1.96	32700	33	49	293	28500	**462**	1310	513	5.1	**2280**	2.53	143	30	520
	5-10 cm	11700	5.0	**25.4**	291	1.1	2.27	32600	37	**56**	**371**	37200	**675**	1050	595	5.3	**3260**	2.91	183	31	629
	10-20 cm	12400	6.6	**31.7**	311	1.2	2.53	30000	40	**68**	**435**	48100	**662**	9930	672	5.4	**4830**	4.37	195	32	692
2292457 (Back yard)	0-5 cm	13100	3.1	5.0	66	0.5	0.81	8580	18	17	70	16300	104	3740	285	3.3	**487**	<0.3	46	29	176
	5-10 cm	13000	2.6	4.0	56	0.5	0.64	7130	17	15	59	15700	84	3540	255	3.2	**425**	<0.3	35	28	146
	10-20 cm	12300	3.1	5.7	78	0.6	0.75	8450	19	17	87	17600	175	3520	259	3.3	**665**	<0.3	48	26	182
2292458 (Front yard)	0-5 cm	22600	<0.4	5.5	134	1.1	0.94	11500	33	30	120	19900	93	7030	448	4.0	**709**	<0.3	48	49	161
	5-10 cm	22300	<0.4	4.6	127	1.1	0.80	11200	30	26	101	19400	76	6970	400	3.6	**601**	<0.3	46	47	138
	10-20 cm	22400	<0.4	5.7	124	1.1	0.74	12200	30	26	102	21500	71	7520	466	4.0	**696**	<0.3	49	46	142
2292459 (Back yard)	0-5 cm	15000	<0.4	6.2	90	0.7	0.98	6050	21	26	118	17900	101	3150	289	3.2	**864**	<0.3	27	33	212
	5-10 cm	14400	<0.4	4.2	71	0.7	0.67	4580	18	17	67	14500	61	2650	229	2.6	**442**	<0.3	22	30	132
	10-20 cm	17100	<0.4	12.7	137	1	1.57	11600	27	35	180	24200	149	4960	383	3.8	**1670**	<0.3	48	35	319
2292460 (Front yard)	0-5 cm	16100	<0.4	4.9	89	0.9	0.57	9700	23	18	91	21100	61	5600	520	3.5	**579**	<0.3	35	34	123
	5-10 cm	16500	<0.4	6.2	92	0.9	0.59	10200	24	20	98	22400	71	5790	546	3.6	**655**	<0.3	38	34	129
	10-20 cm	19000	<0.4	9.0	111	1.1	0.89	14000	30	31	178	27200	113	7280	511	4.0	**1310**	<0.3	52	39	192
2292461 (Back yard)	0-5 cm	17000	<0.4	8.5	105	1	0.91	13600	26	26	114	20700	74	6240	393	3.9	**1070**	<0.3	71	37	164
	5-10 cm	18200	<0.4	8.6	110	1.1	0.91	13200	26	26	113	21400	72	6130	377	3.7	**1020**	<0.3	75	38	160
	10-20 cm	21700	<0.4	8.0	122	1.2	0.91	11400	29	25	110	23800	76	6040	425	3.8	**1100**	<0.3	72	41	165

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2292462 (Front yard)	0-5 cm	15700	<0.4	7.6	97	0.9	0.78	12100	25	22	95	21100	91	6740	435	4.2	749	<0.3	39	35	187
	5-10 cm	17300	<0.4	8.0	101	0.9	0.74	12500	25	23	102	22700	87	7590	459	3.9	780	<0.3	42	38	177
	10-20 cm	18500	<0.4	10.8	117	1	0.99	15400	28	30	144	26800	119	9160	469	4.2	1250	<0.3	53	39	234
2292463 (Back yard)	0-5 cm	14400	<0.4	9.0	92	0.8	1.01	12500	21	22	109	17900	77	4500	407	3.7	903	<0.3	59	33	174
	5-10 cm	13900	<0.4	9.5	91	0.8	0.93	11000	21	23	109	18000	71	4610	374	3.4	987	<0.3	57	33	161
	10-20 cm	15200	<0.4	8.1	91	0.8	0.78	9810	21	19	91	17900	53	4480	361	3.3	790	<0.3	54	33	143
2292464 (Front yard)	0-5 cm	19600	<0.4	8.3	125	1.1	0.99	15300	30	27	111	24200	91	8710	436	4.3	884	<0.3	69	42	216
	0-5 cm	24800	<0.4	8.5	141	1.3	1.01	12500	36	28	113	26900	89	7350	468	4.4	937	<0.3	60	53	212
	0-5 cm	24400	<0.4	8.9	144	1.3	1.05	12800	37	29	116	26100	104	7660	426	4.2	956	<0.3	61	53	254
	5-10 cm	22300	<0.4	8.6	133	1.2	0.99	13700	32	28	116	27100	88	8180	453	4.3	972	<0.3	65	45	210
	5-10 cm	28400	<0.4	7.7	154	1.4	0.97	11100	38	29	112	29900	86	7540	487	4.1	934	<0.3	61	58	204
	5-10 cm	27800	<0.4	7.1	152	1.3	0.97	10900	37	27	103	28500	86	7440	486	4.0	812	<0.3	61	56	219
	10-20 cm	21700	<0.4	11.0	138	1.2	1.01	13400	32	31	136	28500	96	7520	443	4.0	1240	<0.3	60	44	226
	10-20 cm	27900	<0.4	8.9	154	1.4	1.01	12000	38	30	121	30300	88	7780	468	4.2	1070	<0.3	60	57	207
	10-20 cm	26900	<0.4	10.3	155	1.4	1.03	11300	37	30	124	30000	97	7350	451	4.0	1150	<0.3	62	55	226
2292465 (Back yard)	0-5 cm	20100	<0.4	7.1	121	1.1	1.00	12800	29	21	93	20200	80	6060	356	3.9	618	<0.3	74	44	214
	0-5 cm	18900	<0.4	7.6	116	1	0.95	13200	28	20	86	19000	71	6200	327	3.8	577	<0.3	72	42	191
	0-5 cm	19700	<0.4	6.8	119	1	0.93	12800	29	21	88	19400	94	6090	338	3.8	604	<0.3	77	43	193
	5-10 cm	19400	<0.4	6.6	114	1	0.93	13400	27	21	90	19200	74	6140	360	3.8	638	0.30	71	42	180
	5-10 cm	20600	<0.4	7.3	125	1.1	0.96	14500	30	22	93	20600	76	6660	359	3.8	636	<0.3	81	45	201
	5-10 cm	20400	<0.4	7.3	123	1.1	0.98	13400	29	22	92	19800	76	6340	349	3.9	689	<0.3	84	45	190
	10-20 cm	19600	<0.4	7.8	115	1	0.91	14500	28	20	84	19800	68	6190	344	3.8	622	<0.3	79	43	174
	10-20 cm	20100	<0.4	8.1	125	1.1	0.94	15300	28	21	93	19600	73	6600	339	3.9	594	<0.3	85	42	193
	10-20 cm	21100	<0.4	8.2	125	1.1	0.96	14100	29	21	91	20500	74	6240	347	3.8	700	<0.3	90	44	189
2292466 (Front yard)	0-5 cm	16100	<0.4	5.4	88	0.8	0.60	12900	23	20	71	21600	64	6350	447	3.8	545	<0.3	38	37	140
	5-10 cm	17900	<0.4	5.7	97	0.9	0.64	9910	25	22	75	22800	65	5810	490	3.8	562	<0.3	30	41	138
	10-20 cm	18900	<0.4	5.0	95	0.9	0.55	7900	25	19	59	22600	52	5550	490	3.6	444	<0.3	25	40	116
2292467 (Back yard)	0-5 cm	22700	<0.4	4.7	155	1.2	0.52	21100	32	18	55	26200	161	9330	590	4.4	274	<0.3	77	48	158
	5-10 cm	24100	<0.4	6.0	174	1.3	0.59	23900	34	22	67	28600	143	1030	597	4.5	413	<0.3	91	50	188
	10-20 cm	18600	<0.4	8.3	172	1.1	0.83	20900	30	26	108	26700	197	9080	524	4.7	804	<0.3	93	41	250
2292468 (Front yard)	0-5 cm	16500	<0.4	9.4	118	1	0.91	17000	25	29	147	24800	119	7170	597	4.4	1160	<0.3	52	38	218
	5-10 cm	17400	<0.4	10.5	130	1.1	1.15	17400	28	33	168	26200	133	7410	646	4.6	1250	<0.3	57	41	246
	10-20 cm	14200	<0.4	7.3	85	0.8	0.79	10900	22	27	120	24900	90	5190	601	3.9	1030	<0.3	36	33	181

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2292469 (Back yard)	0-5 cm	14100	<0.4	14.6	175	0.8	1.40	24100	31	24	158	21000	271	6940	487	4.7	974	<0.3	97	32	332
	5-10 cm	15200	<0.4	18.0	220	1.1	1.71	24400	32	30	217	26100	389	6930	567	4.4	1360	<0.3	108	35	396
	10-20 cm	14600	<0.4	14.0	167	0.9	1.13	14800	26	24	125	24500	296	5390	583	4.1	979	<0.3	73	32	270
2292470 (Front yard)	0-5 cm	13100	<0.4	7.7	133	0.8	1.19	24700	24	27	148	17700	234	9220	395	4.3	775	<0.3	77	32	243
	0-5 cm	11100	<0.4	6.4	118	0.7	0.89	20500	21	23	122	15600	192	7870	333	4.1	720	<0.3	62	30	203
	0-5 cm	12300	<0.4	7.9	121	0.8	1.27	23400	24	27	147	18600	203	9730	394	4.4	840	<0.3	74	32	235
	5-10 cm	13700	<0.4	7.6	134	0.8	1.04	22500	25	28	156	18000	232	7850	385	4.2	805	<0.3	69	34	236
	5-10 cm	14900	<0.4	8.8	150	0.9	1.28	23600	27	32	177	20000	271	8250	425	4.3	996	<0.3	74	36	267
	5-10 cm	14100	<0.4	9.3	138	0.9	1.18	23800	26	33	185	21900	238	8930	434	4.7	1090	<0.3	72	35	265
	10-20 cm	14600	<0.4	7.6	135	0.9	1.03	17000	27	33	161	20100	228	6660	431	3.8	1040	<0.3	52	34	237
	10-20 cm	16200	<0.4	8.9	167	1	1.24	17900	29	34	203	21400	269	6870	468	4.0	1120	<0.3	60	38	273
	10-20 cm	16400	<0.4	10.7	160	1	1.38	20600	31	38	208	23800	258	8080	504	4.6	1300	<0.3	66	39	294
2292471 (Back yard)	0-5 cm	15100	<0.4	6.5	140	1	1.17	18500	25	25	113	18600	207	6960	386	4.1	712	<0.3	64	38	221
	0-5 cm	15200	<0.4	7.4	132	0.9	1.23	17700	24	26	117	19000	188	6840	395	4.0	725	<0.3	62	37	202
	0-5 cm	16700	<0.4	8.3	143	1	1.57	19500	30	29	123	20600	205	7480	412	4.3	734	<0.3	68	39	227
	5-10 cm	16200	<0.4	7.3	137	1	1.13	18700	25	27	114	19600	188	6960	386	4.0	726	<0.3	65	38	202
	5-10 cm	16200	<0.4	6.9	132	1	1.19	17500	24	27	120	20300	176	6650	390	3.9	768	<0.3	61	39	186
	5-10 cm	17600	<0.4	8.2	143	1	1.45	19000	28	29	126	21600	184	7350	407	4.2	825	<0.3	69	42	212
	10-20 cm	19600	<0.4	7.5	143	1.1	1.22	15700	28	27	114	23400	191	6770	461	3.9	814	<0.3	58	43	187
	10-20 cm	18100	<0.4	7.1	136	1.1	1.14	16900	26	29	125	22500	161	6770	459	3.7	908	<0.3	58	41	177
	10-20 cm	21200	<0.4	8.9	164	1.2	1.50	20500	31	34	146	24900	191	8030	478	4.3	966	<0.3	72	47	223
2292472 (Back yard)	0-5 cm	16500	<0.4	3.7	97	0.8	0.49	15300	31	15	49	20000	61	6380	501	3.8	291	<0.3	40	31	116
	5-10 cm	19500	<0.4	3.1	98	0.9	0.38	23100	23	14	34	22700	50	8040	564	3.5	166	<0.3	46	35	86
	10-20 cm	21300	<0.4	5.5	127	1	0.54	28600	27	21	71	27000	73	8600	651	3.8	446	<0.3	66	39	155
2292473 (Front yard)	0-5 cm	19500	<0.4	5.2	130	0.9	0.92	11700	26	29	135	22600	140	6270	584	3.6	906	<0.3	45	37	282
	5-10 cm	22600	<0.4	4.5	128	1	0.82	9220	27	28	139	24500	120	5830	662	3.5	765	<0.3	41	40	208
	10-20 cm	19800	<0.4	7.0	127	0.9	0.99	12600	25	32	193	23300	140	5880	537	3.7	1050	<0.3	56	37	234
2292474 (Front yard)	0-5 cm	24400	<0.4	10.9	232	1.2	1.34	17400	32	44	225	30700	324	7700	450	3.7	1880	<0.3	56	42	407
	5-10 cm	24500	<0.4	15.6	264	1.3	1.50	19800	34	45	257	34600	365	8050	481	4.0	2290	<0.3	62	41	451
	10-20 cm	22100	0.4	18.2	267	1.2	1.45	26500	30	40	224	35700	413	7810	461	4.1	2440	0.53	74	38	504
2292475 (Back yard)	0-5 cm	10200	<0.4	1.6	75	0.4	0.44	9860	11	6	15	9890	33	3340	170	2.7	87	<0.3	23	20	87
	5-10 cm	10600	<0.4	2.0	174	0.5	0.42	10200	12	7	18	11200	37	3150	192	2.7	144	<0.3	24	22	82
	10-20 cm	16000	<0.4	3.6	956	0.8	0.46	20500	20	11	34	17300	86	5970	316	3.4	232	<0.3	49	30	113

Table A1: Chemical analysis of soils collected in the fall of 2000

Site / Location	Soil Depth	Al	Sb	As	Ba	Be	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	Sr	V	Zn
2292476 (Front yard)	0-5 cm	20700	<0.4	4.9	136	0.9	0.80	23400	27	33	143	24000	183	9760	419	3.9	**1020**	<0.3	55	37	220
	5-10 cm	23900	<0.4	6.2	150	1.1	0.81	23300	27	32	145	25800	172	9490	417	3.8	**1100**	<0.3	56	40	218
	10-20 cm	19900	<0.4	6.7	130	1	0.69	27900	24	30	134	25000	138	1040	459	3.7	**1100**	<0.3	58	35	198
2292477 (Back yard)	0-5 cm	22300	5.7	12.7	246	1.2	1.54	13500	39	38	253	34800	**847**	5840	504	4.1	**1910**	0.30	59	40	565
	5-10 cm	21900	11.3	13.0	253	1.2	1.50	13300	37	36	223	34500	**960**	5890	496	4.0	**1810**	0.38	58	38	507
	10-20 cm	23200	9.6	16.3	372	**1.3**	1.76	17600	41	43	**331**	38700	1170	6440	502	4.3	**2540**	0.82	77	39	643
2292478 (Front yard)	0-5 cm	27000	<0.4	6.3	164	1.2	0.98	15000	32	38	173	25600	156	7240	371	4.0	**1380**	<0.3	58	45	240
	5-10 cm	29000	<0.4	6.8	173	1.2	0.99	13300	32	39	170	26800	169	7000	379	3.7	**1410**	<0.3	57	45	242
	10-20 cm	25900	<0.4	11.2	193	1.2	1.17	16400	34	47	259	31000	187	7200	469	4.2	**2570**	<0.3	57	41	310
2292479 (Back yard)	0-5 cm	17200	0.9	16.7	264	**1.4**	1.69	18500	29	50	295	28900	**299**	5280	418	4.0	**2520**	1.10	115	36	579
	5-10 cm	18900	0.5	21.0	378	**1.9**	1.84	24300	33	50	**357**	29000	**387**	5210	423	4.4	**2970**	0.95	199	37	750
	10-20 cm	14400	1.3	17.0	420	**1.8**	1.47	30300	28	41	**377**	26900	**483**	5090	372	4.4	**2530**	0.34	219	30	733
2292480 (Front yard)	0-5 cm	21400	<0.4	5.2	117	1	0.65	16800	25	24	94	22400	75	8500	378	3.7	**785**	<0.3	44	38	147
	5-10 cm	23300	<0.4	4.5	127	1.1	0.61	16500	27	24	91	23600	73	8790	404	3.7	**739**	<0.3	43	40	144
	10-20 cm	23000	<0.4	4.6	125	1	0.68	15600	26	28	107	24600	84	8490	409	3.7	**956**	<0.3	41	39	152
2292481 (Back yard)	0-5 cm	18000	<0.4	5.4	113	0.9	0.72	13400	23	20	83	18600	75	5940	257	3.1	**677**	<0.3	60	35	164
	5-10 cm	21700	<0.4	6.7	128	1.1	0.89	16600	28	24	100	21600	89	6740	296	3.4	**793**	<0.3	77	39	193
	10-20 cm	19100	<0.4	6.6	125	1	0.81	19800	25	23	104	20100	85	7080	288	3.5	**811**	<0.3	77	35	189
2292482 (Front yard)	0-5 cm	17000	<0.4	8.6	112	1	0.80	13700	24	49	181	23600	93	6400	440	3.5	**1700**	0.47	46	36	208
	0-5 cm	17300	<0.4	8.3	117	1	0.86	14100	26	50	184	24800	101	6700	465	3.7	**1800**	0.35	46	37	219
	0-5 cm	21900	<0.4	8.4	143	1.2	0.93	15400	30	48	182	25900	106	7540	495	4.0	**1580**	<0.3	53	49	238
	5-10 cm	24400	<0.4	8.5	146	**1.3**	0.88	14100	32	50	185	28200	92	7660	481	3.6	**1800**	<0.3	47	45	208
	5-10 cm	26400	<0.4	6.3	155	**1.4**	0.79	14200	32	43	161	27800	88	8090	493	3.9	**1390**	<0.3	58	51	210
	5-10 cm	32800	<0.4	4.8	183	**1.7**	0.70	14100	38	39	134	30800	82	9530	475	3.8	**1160**	<0.3	53	60	191
	10-20 cm	20200	<0.4	8.7	132	1.2	0.72	17700	26	38	150	27400	77	7370	500	3.6	**1520**	<0.3	48	39	180
	10-20 cm	27000	<0.4	5.4	156	**1.4**	0.67	16100	32	35	129	28700	80	8680	480	3.7	**1180**	<0.3	52	52	177
	10-20 cm	28600	<0.4	6.2	168	**1.5**	0.67	18000	32	38	141	28700	75	9090	496	3.9	**1200**	<0.3	56	54	177

Table A1: Chemical analysis of soils collected in the fall of 2000

Site / Location	Soil Depth	Al	Sb	As	Ba	Be	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	Sr	V	Zn
2292483 (Back yard)	0-5 cm	25400	<0.4	7.8	162	**1.4**	0.79	14300	31	28	108	23000	87	6380	369	3.6	**977**	<0.3	65	46	186
	0-5 cm	24800	<0.4	6.9	164	**1.3**	0.77	13600	28	27	109	22900	96	6180	367	3.6	**930**	<0.3	63	45	187
	0-5 cm	25800	<0.4	7.4	167	**1.4**	0.81	14000	31	28	111	23900	89	6390	381	4.0	**929**	<0.3	64	47	188
	5-10 cm	27900	<0.4	8.9	197	**1.5**	0.77	14700	32	29	110	24400	86	6730	374	3.7	**963**	<0.3	68	49	187
	5-10 cm	26800	<0.4	6.8	168	**1.4**	0.80	14600	30	29	113	23900	89	6530	380	3.5	**975**	<0.3	65	48	191
	5-10 cm	26300	<0.4	7.9	164	**1.4**	0.76	12800	30	28	107	23700	83	6380	362	3.4	**942**	<0.3	61	48	183
	10-20 cm	28500	<0.4	9.6	183	**1.5**	0.79	16300	32	27	107	25200	95	6860	367	3.9	**998**	<0.3	72	49	187
	10-20 cm	24700	<0.4	8.0	159	**1.3**	0.68	14700	28	24	97	22300	75	6300	331	3.4	**834**	<0.3	61	44	169
	10-20 cm	27100	<0.4	9.6	171	**1.4**	0.76	15100	32	26	104	24400	82	6650	355	3.6	**930**	<0.3	69	48	178
2292484 (Front yard)	0-5 cm	19700	<0.4	8.7	122	1.1	0.87	17700	28	22	89	21500	134	9220	423	5.5	**629**	<0.3	62	43	182
	5-10 cm	21900	<0.4	6.1	130	1.2	0.83	14800	29	24	89	23600	125	8250	454	5.3	**648**	<0.3	61	47	179
	10-20 cm	20500	<0.4	6.0	115	1.1	0.80	13800	27	24	89	23100	114	7200	480	5.5	**738**	<0.3	61	43	163
2292485 (Back yard)	0-5 cm	15400	<0.4	17.8	181	0.9	1.93	22600	32	23	131	20500	**313**	9490	312	6.2	**765**	<0.3	89	36	375
	5-10 cm	17800	<0.4	15.1	202	**1.3**	2.20	24500	32	26	139	22000	**372**	8540	338	6.0	**871**	<0.3	95	40	390
	10-20 cm	28400	<0.4	11.2	228	**1.5**	1.81	25600	39	27	220	28900	**259**	1170	383	6.1	**703**	<0.3	104	56	316
2292486 (Front yard)	0-5 cm	14300	<0.4	9.3	160	1	1.20	32500	26	29	145	21000	**277**	1420	458	6.7	**1010**	<0.3	79	37	274
	5-10 cm	17300	<0.4	9.3	178	1.1	1.33	35700	28	31	151	23400	**271**	1630	490	6.7	**1010**	<0.3	80	42	279
	10-20 cm	17500	<0.4	10.9	185	1	1.04	45500	26	31	145	24300	**406**	2030	491	7.0	**1300**	<0.3	84	38	253
2292487 (Back yard)	0-5 cm	14300	<0.4	2.2	83	0.8	1.26	9400	21	17	58	18200	92	5700	630	4.9	**207**	<0.3	40	34	155
	5-10 cm	13500	<0.4	1.4	54	0.7	0.62	4650	17	12	34	18300	44	4210	542	4.1	99	<0.3	24	31	75
	10-20 cm	12900	<0.4	1.5	46	0.7	0.44	2880	15	10	20	17400	25	3630	587	3.4	46	<0.3	17	28	52
2292488 (Front yard)	0-5 cm	19500	<0.4	7.7	143	1.1	1.10	16000	28	28	129	22100	168	7320	374	5.7	**970**	<0.3	62	44	232
	5-10 cm	22600	<0.4	7.8	159	1.2	1.17	17300	30	30	130	24600	160	8220	411	5.7	**968**	<0.3	64	49	232
	10-20 cm	27100	<0.4	7.0	172	**1.4**	0.85	27700	33	30	130	29700	125	1120	466	6.1	**917**	<0.3	85	53	187
2292489 (Back yard)	0-5 cm	26300	<0.4	8.3	192	**1.4**	1.13	22600	35	24	104	26300	153	8940	492	5.7	**644**	<0.3	82	54	246
	5-10 cm	28700	<0.4	8.8	200	**1.5**	1.98	22600	36	23	89	29700	148	1060	471	6.0	**586**	<0.3	73	57	658
	10-20 cm	33900	<0.4	6.0	249	**1.7**	0.96	20600	41	27	95	32800	158	1040	541	5.8	**637**	<0.3	76	64	256

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Site / Location	Soil Depth	Al	Sb	As	Ba	Be	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	Sr	V	Zn
2292490 (Front yard)	0-5 cm	21900	<0.4	6.7	157	**1.3**	1.87	12700	41	32	134	32400	178	5870	521	5.8	**953**	<0.3	57	47	334
	0-5 cm	19100	<0.4	7.9	140	1.2	1.87	14600	38	31	140	30300	182	6060	502	5.8	**926**	<0.3	60	41	339
	0-5 cm	21400	<0.4	8.0	150	**1.3**	2.23	14400	38	30	132	29700	169	6160	562	5.9	**921**	<0.3	59	44	303
	5-10 cm	24200	<0.4	7.3	149	**1.4**	1.67	11900	43	31	130	30500	152	6060	497	5.8	**971**	<0.3	54	50	284
	5-10 cm	20100	<0.4	7.6	129	1.2	1.60	12000	36	29	125	28900	147	5680	467	5.5	**918**	<0.3	51	41	278
	5-10 cm	22000	<0.4	7.3	140	**1.3**	1.64	11900	37	29	128	28600	150	5780	491	5.8	**907**	<0.3	52	44	272
	10-20 cm	22200	<0.4	13.7	180	**1.6**	2.38	22700	43	36	220	48900	**264**	5950	736	7.2	**1200**	0.40	106	39	561
	10-20 cm	22200	<0.4	13.8	172	**1.6**	2.34	21400	40	34	174	37800	**224**	6050	671	6.4	**1230**	<0.3	93	42	436
	10-20 cm	20500	<0.4	12.3	167	**1.5**	2.11	20700	36	32	164	34600	**227**	5680	588	6.0	**1250**	<0.3	90	39	387
2292491 (Back yard)	0-5 cm	23200	<0.4	7.5	154	**1.3**	0.74	30200	30	21	79	26200	93	1460	523	6.2	**484**	<0.3	87	47	169
	0-5 cm	20000	<0.4	8.6	146	1.2	1.02	23900	28	22	92	25600	115	1150	484	6.0	**617**	<0.3	85	42	207
	0-5 cm	20200	<0.4	9.5	147	1.2	1.02	26000	28	23	98	24800	128	1190	469	5.8	**677**	<0.3	97	43	212
	5-10 cm	19800	<0.4	8.3	147	1.2	0.76	35900	26	21	84	25300	91	1530	536	6.6	**541**	<0.3	100	40	185
	5-10 cm	24700	<0.4	6.2	157	**1.3**	0.74	36000	31	21	83	28600	113	1390	503	5.8	**553**	<0.3	104	46	163
	5-10 cm	21700	<0.4	8.8	150	**1.3**	0.97	24900	29	23	91	26700	99	1110	512	6.1	**648**	<0.3	95	45	186
	10-20 cm	20600	<0.4	7.9	141	1.2	0.60	37000	26	18	68	25200	78	1430	494	6.5	**396**	<0.3	98	40	128
	10-20 cm	22900	<0.4	8.4	163	**1.3**	0.87	25100	30	24	94	28100	113	1160	583	6.0	**662**	<0.3	92	46	191
	10-20 cm	26600	<0.4	7.0	160	**1.4**	0.80	33200	33	21	77	30000	91	1250	504	5.7	**529**	<0.3	118	50	
2292492 (Front yard)	0-5 cm	14100	<0.4	3.5	61	0.6	0.47	4800	15	11	38	13000	56	2390	160	3.8	**296**	<0.3	21	26	83
	5-10 cm	13400	<0.4	2.4	52	0.5	0.41	3760	13	10	30	11600	47	1970	137	3.3	**221**	<0.3	17	24	68
	10-20 cm	14900	<0.4	2.8	49	0.5	0.40	3090	13	9	25	12600	39	1890	131	3.2	192	<0.3	14	25	61
2292493 (Back yard)	0-5 cm	17400	<0.4	17.9	191	**1.3**	1.42	30200	27	27	160	22800	**219**	1240	354	6.4	**1080**	<0.3	180	42	267
	5-10 cm	14600	<0.4	13.9	149	1.1	1.20	23500	24	25	139	19900	**207**	1030	308	6.3	**1010**	<0.3	134	38	242
2292494 (Front yard)	0-5 cm	20500	<0.4	6.7	127	1.1	1.09	10200	29	23	96	23500	120	5910	495	4.9	**725**	<0.3	41	44	209
	5-10 cm	20400	<0.4	4.8	122	1.1	0.90	9670	27	22	87	23400	101	5720	526	5.0	**662**	<0.3	39	43	181
	10-20 cm	24000	<0.4	9.8	139	1.2	0.57	14000	29	23	101	27400	106	7280	492	1.7	**786**	<0.3	52	46	206
2292495 (Back yard)	0-5 cm	16900	0.4	11.8	114	0.8	0.68	8500	22	19	95	18800	116	3810	308	1.7	**637**	<0.3	54	36	212
	5-10 cm	17400	0.5	13.2	118	0.8	0.67	8190	22	20	97	19400	113	3860	309	1.4	**702**	<0.3	54	37	196
	10-20 cm	19000	<0.4	13.9	124	0.8	0.65	8020	23	19	87	19400	114	4060	311	1.4	**620**	<0.3	56	39	185
2292496 (Front yard)	0-5 cm	26000	0.8	13.5	177	1.2	1.22	13700	36	38	150	27300	**221**	7140	437	2.3	**1070**	<0.3	68	56	374
	5-10 cm	27700	0.7	14.5	197	**1.3**	1.32	12800	36	40	156	29200	**210**	7350	744	2.3	**1110**	<0.3	67	58	351
	10-20 cm	21900	0.6	**27.7**	153	1	1.36	15300	30	30	129	26500	**270**	6930	372	2.2	**1070**	<0.3	64	50	338

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Site / Location	Soil Depth	Al	Sb	As	Ba	Be	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	Sr	V	Zn
2292497 (Back yard)	0-5 cm	15300	1.3	14.4	200	0.8	1.51	21600	26	24	127	20100	469	8590	309	2.1	1100	<0.3	86	37	419
	5-10 cm	15400	3.1	17.3	298	0.8	1.51	24400	29	26	204	20400	1200	8050	339	2.0	1770	<0.3	94	37	556
	10-20 cm	20100	1.4	18.8	258	1.1	1.33	22300	30	25	145	23800	385	7840	329	2.3	1180	<0.3	126	44	407
2292498 (Front yard)	0-5 cm	27100	0.7	12.0	187	1.3	0.95	14800	40	36	161	27800	221	7780	495	2.3	1180	<0.3	58	55	289
	5-10 cm	24900	0.5	11.4	186	1.2	1.00	13100	38	32	146	26500	194	7020	452	2.0	1170	<0.3	52	51	248
	10-20 cm	25000	0.5	14.1	177	1.2	0.69	18700	35	34	166	29000	245	8000	477	2.1	1600	<0.3	66	50	268
2292499 (Back yard)	0-5 cm	30600	<0.4	19.3	189	1.3	1.20	12400	37	24	109	24300	123	6350	484	2.1	640	<0.3	100	58	220
	5-10 cm	30800	0.6	20.0	189	1.3	1.24	11400	36	23	106	24700	122	5960	496	2.1	624	<0.3	102	58	207
	10-20 cm	33000	0.7	21.1	198	1.4	1.23	13400	37	23	110	26500	126	6380	449	1.9	653	<0.3	117	60	200
2292500 (Front yard)	0-5 cm	31100	0.5	9.3	185	1.3	1.04	17000	39	32	137	24300	194	8270	379	2.1	1060	<0.3	62	58	238
	5-10 cm	32300	0.5	10.5	199	1.3	1.43	12500	40	33	143	24100	210	7790	371	2.0	1060	<0.3	59	59	245
	10-20 cm	33000	0.5	11.2	189	1.3	0.97	12800	38	30	135	26400	171	8170	419	2.0	1220	<0.3	63	58	214
2292501 (Back yard)	0-5 cm	37700	<0.4	8.4	225	1.7	1.13	14300	46	28	109	27000	124	8530	359	2.2	642	<0.3	87	68	227
	5-10 cm	40000	0.4	8.7	243	1.7	1.29	16500	46	26	100	29300	118	9320	395	2.1	515	<0.3	92	70	207
	10-20 cm	34900	0.5	7.5	237	1.6	0.88	21100	42	23	68	33200	93	1070	518	2.0	340	<0.3	89	62	196
2292502 (Front yard)	0-5 cm	25200	0.8	17.0	177	1.3	0.81	15200	36	36	177	28400	204	7630	409	2.3	1450	<0.3	78	51	340
	5-10 cm	27300	0.8	19.1	204	1.4	0.80	15000	38	38	177	31900	210	8350	467	2.1	1620	<0.3	79	54	342
	10-20 cm	25700	0.9	26.7	190	1.3	0.75	18300	35	39	207	31600	197	8300	456	2.4	1980	<0.3	90	51	300
2292503 (Back yard)	0-5 cm	19900	1.5	18.2	317	1.1	1.05	24800	36	35	173	28300	259	8080	410	2.7	1390	0.40	134	48	492
	5-10 cm	23000	1.8	26.1	380	1.3	1.36	24800	43	40	208	31700	280	8240	457	2.7	1630	0.40	160	54	575
	10-20 cm	23300	1.9	25.0	384	1.4	1.29	26300	40	36	215	31600	268	8030	454	2.8	1480	<0.3	178	54	540
2292504 (Back yard)	0-5 cm	20700	1.7	18.3	251	1.3	2.78	26600	40	58	269	32300	330	1020	576	3.1	1970	0.70	114	55	992
	5-10 cm	22400	1.6	18.6	263	1.4	1.98	25500	38	47	237	33900	236	9380	540	2.8	2010	<0.3	128	52	727
	10-20 cm	22800	1.7	17.7	295	1.5	1.13	30800	35	37	279	31500	213	1000	497	2.5	1540	<0.3	153	49	561
2292505 (Front yard)	0-5 cm	18600	0.4	12.1	197	0.9	0.95	29100	28	24	115	23100	152	9220	548	2.2	801	0.40	82	39	343
	5-10 cm	19800	0.7	15.7	198	1	1.10	23100	30	31	154	26200	183	9340	502	2.3	1300	<0.3	73	44	343
	10-20 cm	19600	1.2	14.8	194	1	0.84	22600	30	34	241	28300	269	9270	552	2.1	1470	0.50	74	45	327
2292506 (Back yard)	0-5 cm	26500	<0.4	8.1	195	1.3	1.42	19800	35	23	113	25200	138	8930	349	5.5	683	<0.3	90	50	296
	5-10 cm	22700	<0.4	9.7	188	1.1	0.75	44600	30	21	95	26200	117	1910	440	2.1	560	<0.3	131	45	228
	10-20 cm	28600	<0.4	8.1	204	1.5	1.52	27500	38	24	103	25800	113	1380	396	6.4	641	<0.3	107	52	280
2292507 (Front yard)	0-5 cm	18300	<0.4	10.0	152	1.1	1.41	23400	31	32	148	24900	248	1030	484	6.0	1120	<0.3	67	42	330
	5-10 cm	21500	<0.4	13.4	194	1.3	1.63	23400	37	39	196	29200	302	1070	526	6.4	1640	<0.3	73	45	369
	10-20 cm	21700	<0.4	14.5	183	1.3	1.58	23300	33	37	176	30300	260	1000	511	6.0	1700	<0.3	83	44	350

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Site / Location	Soil Depth	Al	Sb	As	Ba	Be	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	Sr	V	Zn
2292508 (Back yard)	0-5 cm	25500	<0.4	9.5	180	**1.4**	1.49	14200	36	25	102	26500	160	7600	430	5.6	**603**	<0.3	59	52	256
	5-10 cm	26800	<0.4	7.2	168	**1.4**	1.38	12300	35	25	93	27100	122	8030	432	5.3	**563**	<0.3	51	53	216
	10-20 cm	26900	<0.4	9.8	178	**1.5**	1.48	14000	36	23	99	26000	143	7920	404	5.4	**608**	<0.3	61	53	226
2292509 (Front yard)	0-5 cm	13200	<0.4	4.3	82	0.7	0.63	9870	21	15	51	16900	94	4810	392	4.6	**290**	<0.3	32	31	140
	5-10 cm	13700	<0.4	5.4	99	0.7	0.62	14500	20	16	54	17900	125	5350	410	5.0	**352**	0.80	40	32	150
	10-20 cm	15000	<0.4	5.9	111	0.8	0.78	12900	25	22	74	20900	126	5830	462	5.0	**578**	0.40	44	36	190
2292510 (Back yard)	0-5 cm	13700	<0.4	6.7	149	0.7	1.00	15400	23	17	70	15800	**260**	6430	329	5.2	**429**	<0.3	53	30	276
	5-10 cm	14100	<0.4	6.7	165	0.8	1.11	17500	24	18	75	17500	**313**	7060	380	5.4	**474**	<0.3	61	33	311
	10-20 cm	14200	<0.4	7.9	160	0.8	1.18	18200	24	18	86	17900	**320**	7110	360	5.8	**461**	<0.3	64	32	302
2292511 (Back yard)	0-5 cm	16000	<0.4	5.7	94	0.6	0.44	12400	23	16	49	20100	74	6480	405	5.6	**357**	<0.3	47	40	136
	5-10 cm	17500	<0.4	5.3	95	0.7	0.35	14800	24	17	48	21300	63	7230	455	5.6	**337**	<0.3	63	44	125
	10-20 cm	11800	<0.4	4.4	61	0.4	0.29	18500	20	17	49	20400	47	7200	415	5.5	**421**	0.30	60	42	141
2292512 (Front yard)	0-5 cm	16500	<0.4	8.9	132	0.9	0.89	28400	27	33	174	21500	**214**	1270	472	6.1	**1010**	<0.3	91	41	314
	5-10 cm	18500	<0.4	10.5	139	1	0.92	29700	28	36	211	23200	**277**	1300	490	6.6	**1120**	<0.3	96	44	416
	10-20 cm	22200	0.5	11.6	144	1.1	0.77	24300	30	33	153	27000	**247**	1050	573	7.4	**1090**	<0.3	88	47	297
2292513 (Back yard)	0-5 cm	15300	6.8	15.3	446	0.7	2.10	15100	28	25	**1100**	21500	1350	5380	534	6.8	**847**	<0.3	77	39	**1210**
	5-10 cm	18400	2.5	**25.7**	284	1.3	1.84	21000	34	38	277	30500	**352**	6310	539	8.4	**1930**	0.40	131	43	583
	10-20 cm	15900	1.5	15.3	187	0.7	1.13	14000	27	26	201	22800	**251**	5020	480	6.8	**990**	<0.3	69	38	370
2292514 (Front yard)	0-5 cm	17400	1.0	14.4	197	1.1	1.17	35400	32	**51**	281	26300	**290**	1280	686	8.0	**1590**	<0.3	130	46	409
	5-10 cm	16100	1.0	15.2	190	1.1	1.19	35000	29	49	**323**	26100	**302**	1240	753	8.2	**1600**	<0.3	173	45	396
	10-20 cm	15000	1.2	16.3	174	0.9	0.77	31800	30	47	255	31200	**269**	9950	769	8.3	**2160**	0.40	110	40	356
2292515 (Back yard)	0-5 cm	17100	3.5	17.2	511	**2.2**	1.43	62100	32	44	226	34500	**414**	1100	2030	9.7	**1950**	0.80	151	39	643
	5-10 cm	14600	4.5	21.3	534	**1.8**	1.55	52900	34	39	222	42100	**587**	7950	3880	11.4	**2050**	1.20	169	33	685
	10-20 cm	14400	3.2	20.0	397	**1.5**	1.57	45500	35	28	175	37200	**461**	7260	2500	10.2	**1330**	0.50	179	32	544
2292516 (Front yard)	0-5 cm	19000	<0.4	8.4	124	0.8	0.52	15100	26	22	100	21400	137	6390	381	5.9	**668**	<0.3	55	42	177
	5-10 cm	21400	<0.4	9.5	139	1	0.53	15400	29	26	120	22700	132	7020	399	6.4	**735**	<0.3	55	45	185
	10-20 cm	21300	<0.4	8.6	129	0.9	0.47	15500	28	28	132	23400	116	7030	440	6.9	**772**	<0.3	50	46	175
2292517 (Front yard)	0-5 cm	26100	0.7	11.0	170	1.2	0.55	14900	35	43	199	28900	197	8410	522	8.1	**1090**	<0.3	61	60	545
	5-10 cm	29700	<0.4	9.1	172	**1.3**	0.54	9960	38	32	128	30900	128	7980	554	7.9	**688**	<0.3	47	61	301
	10-20 cm	27800	1.4	12.0	256	**1.3**	0.62	16700	39	34	152	33100	**363**	9610	571	8.8	**1210**	<0.3	62	55	590
2292518 (Back yard)	0-5 cm	14900	<0.4	5.8	90	0.6	0.61	8930	20	16	62	16600	164	4030	324	5.4	**380**	<0.3	34	35	173
	5-10 cm	15100	<0.4	5.7	87	0.5	0.60	7720	20	16	59	16000	184	3510	296	5.3	**368**	<0.3	30	35	155
	10-20 cm	16900	<0.4	6.6	113	0.7	0.72	9260	21	16	61	17000	162	4390	302	5.4	**412**	<0.3	35	36	169

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Site / Location	Soil Depth	Al	Sb	As	Ba	Be	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	Sr	V	Zn
2292519 (Front yard)	0-5 cm	21400	<0.4	8.6	142	0.9	0.31	19300	28	35	193	22200	121	9310	418	6.6	1270	<0.3	102	48	189
	5-10 cm	23000	0.6	11.6	146	1.1	0.03	25400	30	60	356	21900	101	1100	351	6.9	2690	<0.3	116	49	161
	10-20 cm	23800	<0.4	10.0	166	1.1	0.17	23900	32	39	217	24000	126	1030	497	7.4	1420	<0.3	161	51	193
2292520 (Back yard)	0-5 cm	18500	<0.4	10.0	135	0.9	0.03	24800	25	41	254	22500	94	9250	397	6.4	1870	<0.3	100	40	174
	5-10 cm	18600	<0.4	10.2	133	0.9	0.03	27100	25	44	274	22800	90	1030	383	6.7	1990	<0.3	111	40	163
	10-20 cm	20800	<0.4	9.3	158	1	0.14	33400	27	31	198	25400	92	1070	496	7.2	1260	<0.3	152	43	188
2292521 (Front yard)	0-5 cm	11600	2.3	10.2	163	0.7	0.92	25100	22	25	141	19000	370	8240	444	6.0	713	<0.3	89	29	316
	5-10 cm	12300	1.1	12.0	174	0.7	0.93	25100	23	27	165	19500	444	7700	476	6.3	843	<0.3	90	31	316
	10-20 cm	11300	<0.4	10.2	114	0.6	0.49	25000	21	33	222	18400	221	9660	496	6.2	928	<0.3	72	30	197
2292522 (Back yard)	0-5 cm	17100	<0.4	6.4	115	0.9	0.50	23100	23	14	41	21400	60	8860	385	6.3	202	<0.3	96	37	130
	5-10 cm	29900	<0.4	7.9	188	1.4	0.42	29400	37	21	45	34600	68	1250	563	8.2	208	<0.3	144	57	136
	10-20 cm	33100	<0.4	8.2	197	1.5	0.29	35700	38	21	45	37600	73	1280	609	8.7	203	<0.3	166	58	135
2292523 (Front yard)	0-5 cm	19900	0.8	13.5	201	1.1	1.26	16100	34	44	248	23400	222	7220	385	6.6	1430	<0.3	86	45	358
	5-10 cm	25800	0.7	15.7	230	1.3	1.48	16000	40	51	319	25000	246	7650	406	7.0	1590	<0.3	99	51	365
	10-20 cm	24200	1.0	15.5	219	1.2	1.13	14500	36	36	208	27100	199	6780	387	7.1	1600	<0.3	105	44	305
2292524 (Back yard)	0-5 cm	20200	0.9	19.9	164	1.1	1.07	15300	30	30	170	25500	160	5550	379	6.5	1280	<0.3	147	43	347
	5-10 cm	19200	1.1	19.1	155	1.1	0.89	13800	28	29	158	24100	148	5320	347	6.0	1260	<0.3	135	41	304
	10-20 cm	18700	2.4	20.5	204	1.1	1.00	17200	31	32	212	29700	228	5980	367	6.8	1620	0.30	153	39	381
2292525 (Front yard)	0-5 cm	11000	1.1	11.1	173	0.8	1.29	29800	27	38	249	21400	244	1150	470	5.5	1110	<0.3	73	33	314
	5-10 cm	12500	1.3	16.5	203	0.9	1.86	38200	33	50	507	23700	315	1410	534	6.4	1690	0.60	92	34	351
	10-20 cm	11800	1.7	15.4	347	0.9	1.70	49900	31	47	393	24100	317	1430	492	6.4	1680	0.70	113	31	433
2292526 (Back yard)	0-5 cm	15800	<0.4	6.4	156	0.8	0.63	14700	26	15	70	19300	164	7020	368	5.1	310	<0.3	61	35	208
	5-10 cm	17200	<0.4	6.7	174	0.9	0.70	18700	29	17	74	20400	192	8370	384	5.0	318	<0.3	78	37	229
	10-20 cm	16200	0.9	7.6	212	0.9	1.10	25400	33	17	97	22700	252	1020	431	5.8	365	<0.3	106	37	306
2292527 (Front yard)	0-5 cm	10600	0.7	9.8	191	0.7	0.93	26800	20	26	153	19500	328	9420	337	5.9	972	0.30	92	32	283
	5-10 cm	10400	0.5	9.6	184	0.8	0.91	26600	19	24	141	18000	314	8690	340	5.1	816	<0.3	88	30	267
	10-20 cm	13200	1.4	13.7	287	0.9	1.23	36500	35	30	184	24300	458	9620	394	6.7	1260	0.50	124	34	379
2292528 (Back yard)	0-5 cm	14200	0.9	7.2	135	0.8	0.71	11800	51	21	94	18600	174	4950	307	5.3	585	<0.3	62	32	339
	5-10 cm	16500	0.6	7.0	134	0.9	0.64	11200	34	19	89	17900	168	4910	286	5.3	536	<0.3	62	33	247
	10-20 cm	17800	0.6	7.9	170	1.1	1.00	11000	25	17	81	17700	169	4700	315	5.5	399	<0.3	82	34	1750
2292529 (Front yard)	0-5 cm	12700	<0.4	5.5	100	0.6	0.52	7030	18	14	55	17100	156	3760	361	4.7	273	<0.3	31	29	185
	5-10 cm	14200	<0.4	5.8	109	0.6	0.57	7510	28	16	66	18200	174	4020	396	5.0	349	<0.3	36	32	193
	10-20 cm	13500	<0.4	9.4	152	0.7	0.76	12700	24	25	125	21900	314	5570	452	5.9	784	<0.3	88	35	316

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Site / Location	Soil Depth	Al	Sb	As	Ba	Be	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	Sr	V	Zn
2292530 (Back yard)	0-5 cm	13700	<0.4	7.3	110	0.7	0.62	8580	18	13	71	13400	99	3230	189	4.0	355	<0.3	53	29	148
	5-10 cm	16700	<0.4	9.9	150	0.9	0.76	10000	21	15	83	15400	139	3590	226	4.9	482	<0.3	64	34	184
	10-20 cm	18900	<0.4	13.8	170	1	0.84	13000	26	18	102	20300	177	4900	289	5.1	641	<0.3	74	39	234
2292531 (Front yard)	0-5 cm	18900	<0.4	9.7	168	1.1	0.79	15700	30	28	131	22800	246	6640	399	5.3	687	<0.3	66	45	266
	0-5 cm	17700	<0.4	7.9	156	1	0.75	16900	26	27	136	22200	200	7000	404	5.7	650	<0.3	66	42	223
	0-5 cm	17300	0.7	9.8	162	1.1	0.85	15900	27	31	163	21900	246	6820	376	6.2	844	<0.3	64	42	257
	5-10 cm	21600	<0.4	9.2	186	1.2	0.75	15300	31	29	129	24600	252	7020	417	5.7	656	<0.3	67	49	259
	5-10 cm	19900	0.5	8.5	169	1.1	0.76	16600	29	31	145	23700	210	7340	452	6.4	762	<0.3	68	46	237
	5-10 cm	21400	0.5	9.8	181	1.3	0.76	13800	31	31	141	23900	223	6740	372	6.3	720	<0.3	63	48	247
	10-20 cm	21500	<0.4	7.9	212	1.2	0.51	20000	29	24	82	26700	257	7530	426	5.9	470	<0.3	69	47	227
	10-20 cm	19900	0.7	8.4	205	1.2	0.82	20800	29	30	138	23000	264	7930	364	5.9	772	<0.3	75	44	245
	10-20 cm	21100	<0.4	8.3	190	1.3	0.76	13800	29	29	136	23300	228	6700	367	5.9	685	<0.3	63	46	242
2292532 (Back yard)	0-5 cm	11400	2.1	20.0	263	0.9	1.59	25100	27	30	220	24800	442	5550	432	6.4	1400	1.10	121	37	527
	0-5 cm	8830	2.1	14.6	194	0.7	1.07	19200	21	24	168	19600	354	4660	339	5.6	1070	0.70	88	30	399
	0-5 cm	9530	2.0	16.0	205	0.8	1.38	19400	26	25	167	21100	386	4730	349	6.0	1030	1.00	92	31	429
	5-10 cm	11700	2.4	22.9	287	0.9	1.42	24300	28	32	232	25800	480	5300	446	6.3	1420	1.30	113	37	573
	5-10 cm	10300	2.1	18.7	247	0.8	1.32	21900	24	26	202	21200	409	4630	378	6.4	1170	1.10	101	32	475
	5-10 cm	11700	2.5	22.7	288	0.9	1.57	24000	27	31	211	30200	542	5360	451	7.9	1320	1.60	107	36	540
	10-20 cm	9630	1.8	20.0	269	0.7	1.11	23600	23	23	189	22700	406	4950	361	5.6	1030	1.10	109	35	439
	10-20 cm	9490	2.0	20.0	360	0.8	1.19	23500	26	22	190	20900	637	4380	376	6.2	1060	1.20	111	31	452
	10-20 cm	8990	2.2	16.8	211	0.8	1.09	20100	20	23	157	20100	343	4440	347	6.0	1110	0.90	92	29	404
2292533 (Front yard)	0-5 cm	11700	0.4	10.6	132	0.8	0.65	26900	20	33	198	18600	183	9920	360	5.3	1150	<0.3	73	29	242
	5-10 cm	10900	0.4	11.2	129	0.8	0.58	27200	21	39	205	20700	189	9530	367	5.8	1540	0.40	68	30	264
	10-20 cm	12300	0.5	14.4	170	0.9	0.69	26600	22	39	219	21800	233	9490	385	6.2	1500	0.70	83	31	341
2292534 (Back yard)	0-5 cm	11000	0.8	18.5	256	0.9	1.14	21200	37	24	152	19200	303	5970	297	6.0	997	<0.3	102	31	451
	5-10 cm	15500	1.6	23.5	345	1.3	1.59	26000	30	30	201	23000	444	6890	365	6.6	1260	0.40	142	37	650
	10-20 cm	12000	0.9	18.9	232	1	1.19	24900	22	22	151	19000	302	5990	280	5.7	1020	0.30	124	30	502
2292535 (Front yard)	0-5 cm	15400	0.4	8.4	106	0.8	0.53	19900	25	26	157	19200	135	8270	357	5.6	877	<0.3	72	33	171
	5-10 cm	15300	<0.4	8.3	99	0.8	0.40	18400	23	23	130	19100	110	7200	343	5.8	812	<0.3	66	32	150
	10-20 cm	15100	<0.4	16.8	149	1	1.68	38600	33	71	524	26400	344	1600	542	5.6	2330	2.10	91	37	319
2292536 (Back yard)	0-5 cm	18600	<0.4	16.6	350	1.2	2.03	24000	42	33	211	25900	400	7320	379	4.5	1420	1.10	122	44	566
	5-10 cm	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
	10-20 cm	16000	<0.4	10.8	156	1	1.22	24900	29	32	187	23200	225	1030	488	4.6	1010	<0.3	71	37	311

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Site / Location	Soil Depth	Al	Sb	As	Ba	Be	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	Sr	V	Zn
2292537 (Front yard)	0-5 cm	20600	<0.4	12.9	185	1.2	1.40	29000	31	34	197	27100	259	1090	545	4.7	1130	<0.3	82	43	382
	5-10 cm	20200	<0.4	13.6	195	1.2	1.40	29300	32	35	200	27100	267	1120	565	4.8	1160	<0.3	81	42	386
	10-20 cm	19000	<0.4	16.4	181	1.1	1.47	26300	31	37	219	27900	309	9920	541	4.7	1400	<0.3	87	41	364
2292538 (Back yard)	0-5 cm	20900	<0.4	17.1	224	1.3	2.51	20200	38	54	304	27700	525	7850	440	4.7	1770	0.90	125	50	603
	5-10 cm	22000	<0.4	17.6	236	1.3	2.28	16900	37	42	237	31000	438	7050	429	4.4	1770	0.50	107	44	527
	10-20 cm	20100	<0.4	16.4	240	1.2	1.56	22500	32	26	155	27600	467	7470	413	4.3	1020	<0.3	121	40	363
2292539 (Front yard)	0-5 cm	20700	<0.4	6	122	1	1.00	10700	29	23	83	26300	94	6330	481	5	666	<0.3	38	45	187
	5-10 cm	19700	<0.4	5.0	112	1	0.75	8140	26	20	67	23700	79	5540	467	4.7	544	<0.3	32	42	152
	10-20 cm	19300	<0.4	3.7	101	1	0.61	7260	25	16	48	22300	56	5430	437	4.4	388	<0.3	28	40	126
2292540 (Back yard)	0-5 cm	20500	<0.4	2.5	90	0.7	0.43	3180	25	9	15	17400	51	3310	165	3.3	110	<0.3	27	36	80
	5-10 cm	19700	<0.4	1.1	78	0.7	0.29	1920	23	7	4	15800	31	2880	137	2.8	35	<0.3	17	34	52
	10-20 cm	21800	<0.4	3.6	110	0.8	0.60	5120	28	14	43	19600	89	3890	230	4.2	282	<0.3	35	39	129
2292541 (Front yard)	0-5 cm	20000	<0.4	14.5	165	1	1.89	24700	33	82	337	34800	171	9600	604	4.4	4240	1.45	84	39	398
	5-10 cm	23000	<0.4	21.7	182	1.2	2.43	20000	38	115	477	45500	236	8730	781	4.6	5720	2.25	79	43	435
	10-20 cm	22900	0.6	24.3	173	1.1	2.15	18500	46	100	474	55200	176	8520	720	5.2	6630	2.45	75	41	518
2292542 (Back yard)	0-5 cm	18600	<0.4	8.8	144	0.8	1.22	18700	27	26	137	22400	190	7620	503	3.7	1020	<0.3	58	37	275
	5-10 cm	19400	<0.4	12.5	167	0.9	1.42	22600	29	28	175	23300	272	8800	469	3.7	1200	<0.3	66	39	325
	10-20 cm	18600	1.4	20.3	195	1	1.96	19800	36	64	339	37600	345	7310	511	4.4	3480	1.27	69	37	486
2292543 (Front yard)	0-5 cm	20500	<0.4	6.2	127	1	0.82	17300	26	36	138	22600	102	9910	474	3.7	1440	<0.3	55	41	179
	5-10 cm	21600	<0.4	6.8	128	1.1	0.80	18200	27	32	127	23400	92	1030	516	3.9	1240	<0.3	53	42	164
	10-20 cm	24600	<0.4	6.8	150	1.2	0.81	24800	29	33	151	26100	109	1320	549	4.1	1410	<0.3	71	46	179
2292544 (Back yard)	0-5 cm	20300	<0.4	7.5	122	1	0.96	8050	29	35	142	26100	164	6060	486	3.4	1340	<0.3	36	42	268
	5-10 cm	22400	<0.4	6.7	127	1.1	0.95	11100	31	35	146	28100	151	7810	497	3.7	1350	<0.3	39	44	258
	10-20 cm	20700	1.5	16.2	261	1.1	1.91	15500	47	61	326	39600	406	8040	566	4.2	3520	0.92	61	40	673
2292545 (Front yard)	0-5 cm	15900	<0.4	14.0	166	0.9	1.24	23800	26	46	203	27100	219	1080	517	4.3	2410	0.55	166	32	406
	0-5 cm	17700	<0.4	12.7	164	1	1.12	22900	26	40	177	25600	194	1130	467	4.0	1910	<0.3	157	35	346
	0-5 cm	17600	<0.4	13.8	181	1	1.20	24200	28	41	184	26700	216	1130	519	4.3	2060	<0.3	351	35	397
	5-10 cm	19200	<0.4	15.7	184	1	1.35	25700	30	52	229	30900	271	1160	588	4.3	2790	0.52	189	38	456
	5-10 cm	17800	<0.4	17.6	183	1.1	1.39	26100	30	51	239	29300	243	1180	530	4.3	2790	<0.3	200	35	454
	5-10 cm	19700	<0.4	13.4	178	1.1	1.21	23600	29	40	185	28200	197	1130	545	4.2	2010	<0.3	198	39	375
	10-20 cm	14500	0.8	27.2	271	0.9	2.22	22900	32	86	403	38000	598	8280	595	4.5	5370	2.71	208	31	901
	10-20 cm	14600	0.9	24.2	265	0.9	2.15	26200	34	83	387	36600	515	9570	602	4.7	4700	2.26	247	32	793
	10-20 cm	15900	<0.4	23.3	235	1	1.81	24200	31	75	344	34700	412	8730	601	4.5	4190	2.21	247	33	699

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Site / Location	Soil Depth	Al	Sb	As	Ba	Be	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	Sr	V	Zn
2292546 (Back yard)	0-5 cm	13600	<0.4	**29.2**	151	0.7	1.96	17200	25	**61**	**310**	32700	190	4900	517	4.0	**3900**	2.10	91	26	499
	0-5 cm	13500	0.5	**30.4**	156	0.7	2.06	17700	26	**70**	**352**	37600	**208**	4930	582	4.1	**4790**	2.47	94	27	522
	0-5 cm	14100	0.5	**29.8**	160	0.8	2.02	17900	28	**66**	**336**	35400	**252**	4870	547	4.4	**4320**	2.65	96	28	526
	5-10 cm	13600	<0.4	**31.8**	151	0.7	2.03	17700	28	**68**	**333**	36300	196	5020	542	4.2	**4560**	2.37	88	27	502
	5-10 cm	13100	<0.4	**32.8**	153	0.7	2.06	17000	26	**68**	**346**	35800	198	4570	547	4.3	**4600**	2.59	100	26	507
	5-10 cm	12100	0.4	**30.7**	145	0.6	1.92	15700	24	**63**	**323**	32900	**206**	4160	514	3.9	**4160**	2.38	80	24	479
	10-20 cm	14200	0.7	**37.6**	170	0.8	2.31	18900	29	**74**	**370**	39900	**217**	4890	601	4.3	**5060**	3.11	102	27	553
	10-20 cm	14400	0.4	**45.3**	188	0.8	2.65	21500	30	**74**	**428**	37800	**259**	4860	626	4.4	**4740**	4.16	123	28	627
	10-20 cm	13200	1.1	**43.8**	186	0.8	2.56	20000	32	**89**	**459**	42800	**246**	4600	634	4.6	**6590**	4.26	111	26	621
2292547 (Front yard)	0-5 cm	16500	<0.4	21.1	146	1	1.74	16800	36	**82**	**379**	39600	**239**	7030	550	5.1	**5090**	4.09	58	35	486
	5-10 cm	17300	<0.4	24.6	141	1	1.73	19600	33	**79**	**372**	41600	182	8670	577	4.5	**5420**	3.46	56	36	458
	10-20 cm	17300	<0.4	22.8	137	1	1.74	19300	32	**81**	**372**	42800	181	8570	573	4.6	**5530**	2.86	56	37	454
2292548 (Back yard)	0-5 cm	13100	1.7	**31.9**	267	1	2.68	19600	36	**112**	**548**	47000	**431**	5550	631	4.8	**7360**	4.85	102	32	872
	5-10 cm	13500	1.8	**41.9**	301	1	3.47	22300	42	**109**	**645**	53500	**437**	5580	719	5.3	**7580**	4.70	111	31	**1090**
	10-20 cm	11700	2.4	24.9	283	0.9	2.08	20700	29	**54**	**373**	34500	**339**	4800	453	4.2	**3730**	2.97	111	27	727
2292549 (Front yard)	0-5 cm	34500	<0.4	14.1	196	**1.6**	1.46	11300	41	**59**	292	26900	94	7940	343	3.9	**2790**	<0.3	74	59	271
	5-10 cm	36700	<0.4	15.2	214	**1.8**	1.55	9480	44	**57**	295	29200	100	7150	361	3.8	**2790**	<0.3	72	63	239
	10-20 cm	20700	<0.4	15.4	158	1	1.54	17700	32	**63**	287	34400	**224**	6200	487	4.2	**3530**	0.73	75	39	364
2292550 (Back yard)	0-5 cm	16400	<0.4	13.3	256	1.2	1.41	18000	42	39	264	28800	**228**	4620	465	4.3	**2030**	<0.3	133	33	503
	5-10 cm	19100	0.8	12.9	268	**1.3**	1.50	16400	45	43	247	29200	**245**	4750	466	4.3	**2190**	<0.3	132	39	502
	10-20 cm	16100	1.0	22.5	408	**1.9**	2.21	22300	44	**78**	**485**	44000	**429**	5030	564	5.3	**5000**	2.13	232	38	870
2292551 (Front yard)	0-5 cm	15500	<0.4	11.0	126	0.8	1.24	15600	26	49	202	28200	138	5630	458	4.0	**2400**	1.25	78	31	304
	5-10 cm	18700	<0.4	12.2	147	0.9	1.30	15800	28	**54**	267	31800	152	5350	454	4.1	**2610**	1.27	92	36	321
	10-20 cm	18100	<0.4	12.4	148	0.9	1.21	14800	28	**51**	237	35200	135	5450	466	3.9	**2920**	0.95	88	34	320
2292552 (Back yard)	0-5 cm	13600	<0.4	9.0	147	0.7	0.96	10600	23	32	145	24100	144	4230	464	3.5	**1560**	<0.3	39	28	320
	5-10 cm	13400	<0.4	8.9	133	0.7	0.90	10200	24	32	141	23600	130	4170	447	3.5	**1530**	<0.3	36	28	308
	10-20 cm	15300	<0.4	13.8	187	0.8	1.48	15500	32	**52**	269	32300	**215**	5470	481	4.0	**2870**	1.18	59	31	505
2292553 (Front yard)	0-5 cm	14200	3.0	14.4	140	0.8	1.68	17900	28	**73**	289	30600	**206**	5760	493	4.3	**3370**	1.88	71	32	429
	5-10 cm	12300	4.3	24.0	153	0.8	1.89	18300	26	**85**	**382**	36500	**211**	5090	579	4.3	**4980**	3.47	76	27	476
	10-20 cm	12700	7.2	**35.7**	176	0.9	2.36	19400	28	**84**	**471**	40800	**341**	5290	650	4.6	**5860**	4.15	85	25	593
2292554 (Back yard)	0-5 cm	14200	<0.4	**28.6**	112	0.7	1.65	10200	27	**86**	**398**	36800	121	3480	490	3.8	**4940**	3.74	88	30	341
	5-10 cm	15200	<0.4	**27.8**	116	0.8	1.43	9990	29	**60**	**322**	38200	106	3540	445	3.7	**4180**	2.58	98	27	327
	10-20 cm	14900	<0.4	13.1	93	0.6	0.79	7710	22	27	162	19600	55	3470	230	3.0	**1650**	<0.3	73	28	155

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Site / Location	Soil Depth	Al	Sb	As	Ba	Be	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	Sr	V	Zn
2292555 (Back yard)	0-5 cm	14300	1.5	21.5	255	1	2.17	19900	34	<u>68</u>	<u>408</u>	36700	<u>362</u>	5310	526	4.2	<u>4410</u>	2.38	124	29	578
	5-10 cm	14600	2.8	<u>25.4</u>	274	1.1	2.40	20100	35	<u>78</u>	<u>462</u>	42700	<u>336</u>	5420	575	4.3	<u>5280</u>	4.73	137	28	648
	10-20 cm	14500	1.2	<u>25.3</u>	287	1.1	2.12	21200	33	<u>65</u>	<u>420</u>	38000	<u>800</u>	5170	522	4.2	<u>4640</u>	2.00	151	28	609
2292556 (Front yard)	0-5 cm	14400	<0.4	6.7	97	0.7	0.66	15300	19	21	84	17400	66	7090	480	3.6	<u>720</u>	<0.3	50	30	130
	5-10 cm	17500	<0.4	8.4	116	0.9	0.69	12200	21	24	99	19300	82	6580	464	3.4	<u>851</u>	<0.3	46	34	133
	10-20 cm	18100	<0.4	5.6	123	0.9	0.62	17100	23	19	70	20700	150	7690	483	3.7	<u>528</u>	<0.3	49	35	130
2292557 (Back yard)	0-5 cm	10700	<0.4	8.0	83	0.5	0.65	16900	17	23	112	16800	53	4040	386	3.5	<u>1040</u>	<0.3	54	22	141
	5-10 cm	12000	<0.4	11.4	81	0.6	0.81	8710	20	27	133	18400	65	3470	341	2.9	<u>1270</u>	<0.3	43	24	156
	10-20 cm	11800	<0.4	18.5	95	0.6	1.06	8880	20	34	190	21200	82	3170	364	3.0	<u>1680</u>	0.43	56	24	210
2292558 (Front yard)	0-5 cm	8810	<0.4	10.6	89	0.5	1.01	19000	18	30	133	18900	110	6280	392	3.6	<u>1410</u>	<0.3	63	21	230
	0-5 cm	9650	<0.4	11.0	102	0.6	1.13	19000	18	36	162	21000	134	6660	441	3.8	<u>1670</u>	0.47	57	22	280
	0-5 cm	9070	<0.4	10.5	91	0.5	1.25	18400	18	32	143	19200	119	6650	415	3.9	<u>1490</u>	0.45	51	20	283
	5-10 cm	9230	<0.4	13.7	98	0.6	1.31	17400	20	41	189	22500	158	6450	422	3.9	<u>2060</u>	0.56	62	21	299
	5-10 cm	10100	<0.4	14.7	107	0.6	1.30	18000	19	44	200	24900	152	6310	459	3.8	<u>2320</u>	0.57	66	23	310
	5-10 cm	9680	<0.4	13.5	100	0.6	1.26	17300	19	42	198	23200	148	6580	413	4.0	<u>2170</u>	0.54	52	22	291
	10-20 cm	8860	0.7	18.1	129	0.7	1.64	21900	27	<u>53</u>	254	29900	<u>224</u>	6470	471	4.3	<u>2680</u>	1.48	99	20	370
	10-20 cm	8700	<0.4	17.5	137	0.7	1.70	22600	21	<u>61</u>	276	33100	<u>286</u>	7090	493	4.5	<u>3440</u>	1.53	105	20	377
	10-20 cm	10000	<0.4	18.8	146	0.8	1.73	23900	23	<u>57</u>	273	31600	<u>280</u>	7750	504	4.3	<u>2810</u>	1.54	90	23	396
2292559 (Back yard)	0-5 cm	11800	<0.4	9.5	90	0.6	1.35	15200	20	24	113	17600	118	5440	289	3.5	<u>983</u>	<0.3	64	26	213
	0-5 cm	12800	<0.4	7.7	107	0.7	1.33	19100	21	24	122	17600	<u>280</u>	7920	343	3.8	<u>878</u>	<0.3	75	25	239
	0-5 cm	12700	<0.4	8.4	96	0.7	1.29	17900	23	23	106	17400	119	7220	294	3.6	<u>994</u>	<0.3	68	27	220
	5-10 cm	12700	<0.4	14.8	95	0.6	1.37	15900	23	25	115	18200	122	5870	316	3.6	<u>948</u>	<0.3	76	27	208
	5-10 cm	12800	<0.4	6.8	105	0.6	1.22	21600	22	22	116	17600	138	8960	313	3.9	<u>780</u>	<0.3	86	27	207
	5-10 cm	12500	<0.4	7.0	89	0.6	0.89	14100	48	20	142	15100	88	6080	263	3.5	<u>751</u>	<0.3	86	28	421
	10-20 cm	11200	0.4	<u>29.3</u>	150	0.6	3.07	12500	27	<u>54</u>	274	27400	<u>428</u>	4410	427	4.1	<u>2610</u>	1.60	100	24	429
	10-20 cm	13800	<0.4	18.1	139	0.8	1.81	15300	24	40	198	27900	193	5700	470	3.8	<u>1970</u>	<0.3	100	27	348
	10-20 cm	12300	<0.4	15.4	125	0.7	1.51	15000	30	39	200	25400	146	4620	369	3.7	<u>2060</u>	<0.3	102	26	438
2292560 (Front yard)	0-5 cm	8900	<0.4	12.0	95	0.6	1.19	24800	20	36	159	28200	192	7430	505	4.7	<u>1980</u>	<0.3	61	20	311
	5-10 cm	9490	1.4	23.6	123	0.7	2.25	24900	29	<u>71</u>	<u>333</u>	48800	<u>316</u>	7610	753	4.8	<u>4820</u>	2.00	69	20	586
	10-20 cm	7420	<0.4	10.8	77	0.5	0.85	17700	15	25	153	21000	133	5320	377	3.2	<u>1920</u>	<0.3	56	19	225
2292561 (Front yard)	0-5 cm	8090	<0.4	9.2	96	0.5	1.80	23300	29	41	190	29700	<u>225</u>	9100	471	3.7	<u>2150</u>	0.50	51	22	410
	5-10 cm	7200	1.1	17.5	103	0.6	2.06	25800	38	<u>61</u>	278	48000	<u>256</u>	8350	652	4.3	<u>3350</u>	1.40	60	20	647
	10-20 cm	6850	<0.4	17.9	93	0.6	1.82	24400	30	47	235	38300	<u>212</u>	7300	531	3.9	<u>3130</u>	0.80	54	17	466

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Site / Location	Soil Depth	Al	Sb	As	Ba	Be	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	Sr	V	Zn
2292562 (Back yard)	0-5 cm	10400	1.3	18.5	164	0.8	2.39	18900	30	**70**	**334**	39600	**364**	6620	545	4.2	**4020**	2.30	64	22	710
	5-10 cm	8670	1.2	22.0	157	0.7	2.26	20700	29	**60**	**335**	38900	**319**	6340	529	4.1	**3240**	2.50	62	18	691
	10-20 cm	6620	0.8	20.3	135	0.6	1.76	21500	21	47	249	32800	**290**	5610	439	4.0	**2920**	1.80	64	14	551
2292563 (Front yard)	0-5 cm	22500	<0.4	10.6	152	1.2	1.58	22400	45	50	210	25700	173	1040	433	5.1	**1620**	<0.3	62	50	359
	5-10 cm	23800	<0.4	12.5	157	1.2	1.60	18600	48	**63**	277	29100	183	8290	490	4.7	**2320**	0.50	54	50	357
	10-20 cm	23000	0.8	**31.7**	207	**1.3**	2.60	22500	45	**112**	**598**	41000	**263**	8400	540	4.9	**7590**	5.30	72	42	662
2292564 (Back yard)	0-5 cm	23200	1.4	19.1	203	**1.3**	2.30	17700	38	43	282	30200	**274**	6800	413	4.2	**2030**	0.50	85	47	578
	5-10 cm	25200	3.3	**29.3**	323	**1.6**	2.27	19900	42	50	**485**	34600	**446**	6530	346	4.3	**3210**	0.70	119	47	635
	10-20 cm	25500	1.3	**28.6**	266	**1.6**	2.06	21600	40	41	**359**	30200	**258**	6560	297	3.9	**2780**	0.70	133	46	512
2292565 (Front yard)	0-5 cm	23900	<0.4	12.7	190	**1.3**	1.80	22800	35	42	**437**	26000	**244**	9410	392	4.2	**1900**	<0.3	86	47	336
	5-10 cm	26500	<0.4	15.0	202	**1.5**	1.76	24700	36	43	244	28300	**226**	1030	410	4.1	**2140**	0.40	99	50	306
	10-20 cm	26100	<0.4	14.5	202	**1.5**	1.53	24300	35	35	215	27200	**203**	8660	372	5.0	**1930**	<0.3	115	48	273
2292566 (Back yard)	0-5 cm	18800	7.6	19.2	405	**1.5**	2.17	34500	40	**52**	**306**	28000	**717**	1120	495	4.4	**2290**	1.10	347	41	727
	5-10 cm	22100	**13.5**	**25.2**	470	**1.7**	2.17	32300	45	50	**393**	33600	**925**	9970	465	4.4	**2880**	0.50	180	41	779
	10-20 cm	22300	**13.6**	**27.2**	530	**1.6**	2.44	27100	68	46	**372**	32000	**1100**	7930	440	4.9	**2720**	0.50	173	42	**853**
2292567 (Front yard)	0-5 cm	21800	1.5	7.9	155	1.2	1.03	18600	33	31	153	24700	**221**	8390	415	3.5	**1260**	<0.3	63	44	280
	0-5 cm	20500	<0.4	7.2	146	1.1	0.99	19200	29	28	137	24300	126	8280	377	3.6	**1190**	<0.3	69	40	292
	0-5 cm	22400	<0.4	8.9	158	1.2	1.04	18400	32	30	149	26800	128	8380	412	3.7	**1270**	<0.3	66	43	275
	5-10 cm	23700	<0.4	11.6	156	**1.3**	1.21	21400	33	40	199	29200	150	9600	450	3.7	**1920**	<0.3	66	46	301
	5-10 cm	20500	<0.4	9.0	145	1.2	1.03	20800	32	31	167	31900	157	8390	408	3.7	**1980**	<0.3	69	39	263
	5-10 cm	21200	<0.4	8.6	154	1.2	1.07	19900	32	34	175	32500	133	7870	391	3.5	**2150**	<0.3	75	41	294
	10-20 cm	24100	<0.4	12.9	163	**1.4**	1.19	20700	33	40	229	44200	138	8910	404	3.9	**3060**	<0.3	74	44	264
	10-20 cm	22000	<0.4	8.6	148	1.2	0.91	25100	30	30	152	32800	103	9970	427	3.7	**2340**	<0.3	80	40	227
	10-20 cm	27600	<0.4	8.2	174	**1.4**	1.01	21700	35	33	173	36100	121	9180	445	3.6	**1960**	<0.3	68	48	229
2292568 (Back yard)	0-5 cm	20300	<0.4	9.8	217	1.2	1.47	21200	35	33	166	25700	**237**	7980	473	4.0	**1340**	<0.3	107	41	514
	0-5 cm	19000	<0.4	8.4	203	1.2	1.41	19700	34	32	158	25200	**298**	7840	408	3.8	**1350**	<0.3	96	40	498
	0-5 cm	20400	<0.4	8.3	208	1.2	1.47	20600	35	32	157	25400	**230**	8060	409	3.7	**1320**	<0.3	97	41	503
	5-10 cm	19500	<0.4	9.2	195	1.2	1.44	22200	33	33	189	25100	**229**	8300	393	3.7	**1440**	<0.3	102	40	489
	5-10 cm	20400	<0.4	9.3	219	**1.4**	1.43	20200	36	35	178	25700	**252**	8050	412	4.4	**1410**	<0.3	114	45	551
	5-10 cm	20900	<0.4	8.5	199	1.1	1.48	21800	33	32	155	26800	**242**	8110	404	3.7	**1420**	<0.3	95	39	463
	10-20 cm	19800	0.6	8.6	191	1.2	1.31	18300	33	32	165	25300	**223**	7030	370	3.6	**1440**	<0.3	89	40	440
	10-20 cm	20600	0.9	9.7	217	**1.3**	1.50	18100	35	35	178	26200	**280**	7320	391	3.7	**1540**	<0.3	104	41	511
	10-20 cm	21900	<0.4	10.4	216	1.2	1.49	20900	34	34	182	27700	**272**	7810	391	3.7	**1730**	<0.3	96	39	480

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Site / Location	Soil Depth	Al	Sb	As	Ba	Be	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	Sr	V	Zn
2292569 (Front yard)	0-5 cm	30700	<0.4	8.4	159	1.4	1.08	15500	36	32	141	30900	173	8710	437	3.5	1370	<0.3	71	49	259
	5-10 cm	32700	<0.4	7.5	166	1.5	1.01	20600	37	32	137	33900	152	1000	449	3.6	1380	<0.3	82	50	232
	10-20 cm	29600	<0.4	11.0	168	1.4	1.15	28800	34	34	172	33400	172	1070	461	3.6	1870	<0.3	98	45	244
2292570 (Back yard)	0-5 cm	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
	5-10 cm	21100	<0.4	7.8	136	1	0.91	27300	26	28	126	28600	159	9320	473	4.4	1200	<0.3	70	36	245
	10-20 cm	20300	<0.4	9.9	145	1	0.98	33300	27	28	141	29000	168	9290	411	3.8	1490	<0.3	79	34	245
2292571 (Front yard)	0-5 cm	19000	0.5	14.8	222	1	2.05	33400	31	50	242	29800	334	1380	449	4.1	2520	8.00	127	36	578
	5-10 cm	18900	2.3	18.9	180	1	2.33	44300	29	55	286	33900	362	1750	473	4.4	3120	9.00	138	34	565
	10-20 cm	25900	<0.4	13.0	186	1.3	1.42	44500	31	31	176	32600	190	1530	585	4.1	1660	<0.3	197	41	341
2292572 (Front yard)	0-5 cm	19900	<0.4	12.6	223	1.2	1.90	24700	33	46	247	25900	342	1060	484	4.3	1910	<0.3	70	41	542
	5-10 cm	23600	<0.4	19.6	274	1.4	2.10	26200	36	52	294	30700	341	1030	488	4.3	2880	<0.3	125	45	522
	10-20 cm	24200	<0.4	11.5	206	1.4	1.21	35500	32	30	185	26700	222	1270	468	4.2	1450	<0.3	87	44	334
2292573 (Back yard)	0-5 cm	18300	7.9	7.9	123	0.9	0.99	14100	27	21	124	20300	165	6670	476	3.5	563	<0.3	62	36	246
	5-10 cm	17200	34.5	14.1	176	1	1.80	24600	29	36	353	26000	554	9550	443	4.4	1400	<0.3	89	36	471
	10-20 cm	22600	91.1	27.1	326	1.4	2.59	24700	41	46	625	31900	782	9520	428	4.9	2370	<0.3	124	43	822
2292574 (Front yard)	0-5 cm	26800	<0.4	13.5	192	1.4	1.92	15300	37	49	221	31600	239	7950	821	4.1	2080	<0.3	52	52	397
	5-10 cm	30400	<0.4	15.3	243	1.6	1.92	13600	41	51	248	36300	236	8160	731	3.9	2450	<0.3	51	57	400
	10-20 cm	25400	<0.4	8.6	195	1.4	1.40	24400	31	26	198	28800	219	7540	588	4.0	1180	<0.3	67	46	443
2292575 (Front yard)	0-5 cm	15600	<0.4	15.3	187	0.9	1.41	22900	28	65	273	22200	505	8760	478	4.4	2770	<0.3	53	36	565
	5-10 cm	19400	<0.4	23.8	206	1.1	1.72	18100	33	86	617	28000	428	8080	494	4.2	4550	1.20	49	41	607
	10-20 cm	21800	<0.4	15.7	183	1.3	1.09	24300	31	48	245	24500	302	8630	498	3.9	2860	<0.3	62	41	362
2292576 (Back yard)	0-5 cm	14500	<0.4	18.3	177	1	1.36	18000	24	40	220	20300	270	6080	382	3.8	1950	0.40	66	32	356
	5-10 cm	13500	<0.4	18.5	164	0.9	1.20	20700	22	34	192	20100	239	6230	355	3.8	1790	<0.3	69	30	299
	10-20 cm	13000	<0.4	12.9	136	0.8	0.97	21600	18	20	116	15400	196	6590	293	3.7	883	<0.3	74	28	216
2292577 (Front yard)	0-5 cm	20500	<0.4	12.4	186	1.2	1.51	19800	30	54	278	25800	289	9100	445	4.2	2490	<0.3	75	42	365
	0-5 cm	18500	<0.4	9.3	168	1.1	1.29	19200	27	48	233	23600	248	8840	397	4.3	2160	<0.3	69	39	316
	0-5 cm	20100		12.1	194	1.2	1.50	20200	31	55	284	25600	283	9260	436	4.3	2530	<0.3	72	43	377
	5-10 cm	20600	<0.4	20.4	285	1.4	2.04	29500	40	74	504	30300	491	1100	472	4.7	4870	0.60	97	40	588
	5-10 cm	19700	<0.4	17.6	241	1.4	1.77	28200	30	63	381	28000	392	1070	489	4.4	3780	<0.3	107	39	481
	5-10 cm	21000	<0.4	15.8	253	1.4	1.59	27200	30	56	332	26700	383	1010	448	4.2	3020	<0.3	97	41	441
	10-20 cm	22600	0.6	19.0	283	1.4	1.81	30900	32	64	446	33800	456	1010	481	4.5	4770	<0.3	102	41	465
	10-20 cm	20800	<0.4	28.0	323	1.5	2.26	30200	33	82	531	35200	485	9250	502	4.6	5990	1.20	114	38	684
	10-20 cm	20600	<0.4	27.4	327	1.3	2.51	39000	32	80	589	34300	570	1080	524	4.7	6060	1.10	117	37	901

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2292578 (Back yard)	0-5 cm	20500	0.6	12.9	344	1.2	1.84	19100	35	43	282	25900	**493**	6840	390	4.1	**1910**	<0.3	92	42	683
	0-5 cm	17300	0.7	11.3	285	1	1.69	17000	39	39	**437**	23700	**519**	6150	351	4.0	**1740**	<0.3	81	37	596
	0-5 cm	15600	0.7	12.2	244	1	2.09	17400	29	40	238	23200	**384**	6410	351	4.1	**1830**	0.30	73	35	514
	5-10 cm	20000	1.7	16.5	547	1.3	2.31	24800	41	48	**441**	32200	**1430**	7750	431	4.4	**2660**	<0.3	113	38	**960**
	5-10 cm	18300	1.7	19.0	624	1.1	2.43	25000	44	50	**567**	30600	**661**	7370	443	4.5	**2690**	<0.3	116	35	**1100**
	5-10 cm	16600	1.1	16.4	532	1.1	2.15	25000	39	46	**351**	27200	**634**	8060	399	4.4	**2580**	<0.3	103	33	**864**
	10-20 cm	15300	4.2	17.9	502	1.2	1.93	25300	35	36	**350**	26900	**860**	6150	317	4.3	**2360**	<0.3	128	29	**869**
	10-20 cm	14700	1.1	15.3	600	1	1.84	24500	33	35	**327**	25700	**686**	6240	345	4.1	**2230**	<0.3	105	29	**846**
	10-20 cm	12900	1.9	20.4	430	0.9	2.27	25600	37	40	**513**	25700	**746**	6440	335	4.3	**2720**	0.30	108	28	**812**
2292579 (Front yard)	0-5 cm	12000	<0.4	1.2	50	0.6	0.32	6090	19	12	37	17300	37	4330	580	2.7	139	<0.3	20	25	69
	5-10 cm	12100	<0.4	1.9	42	0.6	0.21	5420	15	10	25	18100	20	4070	655	2.4	60	<0.3	18	24	47
	10-20 cm	11300	<0.4	2.1	41	0.6	0.20	11800	15	9	27	32200	20	5550	1140	3.3	64	<0.3	24	24	59
2292580 (Back yard)	0-5 cm	33500	<0.4	15.9	254	1.1	2.48	24900	37	47	250	45800	**338**	7720	386	4.8	**3300**	<0.3	90	37	494
	5-10 cm	37000	<0.4	20.5	287	1.2	2.20	46700	39	47	261	49500	**565**	7940	397	4.3	**3610**	<0.3	114	39	521
	10-20 cm	33600	0.8	21.6	289	1.1	2.12	55000	39	39	241	45700	**707**	8080	385	4.3	**3110**	<0.3	125	34	463
2292581 (Front yard)	0-5 cm	30900	<0.4	21.4	130	0.8	1.32	11100	24	42	212	40400	149	5620	467	3.8	**3220**	<0.3	39	33	282
	5-10 cm	32600	<0.4	21.0	128	0.9	1.39	11800	23	40	186	42900	136	5820	894	3.5	**3250**	<0.3	42	33	256
	10-20 cm	38900	<0.4	19.2	145	1.1	1.21	45300	27	38	196	50200	129	9790	1170	4.0	**3000**	<0.3	62	38	235
2292582 (Back yard)	0-5 cm	14500	<0.4	13.9	90	0.6	1.09	5680	20	22	85	32800	83	2980	421	3.0	**755**	<0.3	29	29	211
	5-10 cm	14400	<0.4	12.2	89	0.6	1.09	5660	20	21	84	33600	84	2970	434	3.1	**722**	<0.3	29	29	212
	10-20 cm	13900	<0.4	18.9	157	0.8	1.44	10700	22	31	149	27000	151	4100	718	3.5	**1480**	<0.3	54	29	427
2292583 (Front yard)	0-5 cm	22500	<0.4	4.5	107	1	0.91	9070	26	33	109	23200	68	5260	371	4.0	**864**	<0.3	40	43	256
	5-10 cm	17200	<0.4	4.9	98	0.9	0.78	7650	24	34	140	22100	66	4410	356	3.3	**1140**	<0.3	42	39	197
	10-20 cm	25200	<0.4	7.0	130	1.1	0.88	16300	28	37	154	28900	65	8720	481	3.7	**1600**	<0.3	54	46	218
2292584 (Front yard)	0-5 cm	21000	<0.4	7.8	154	1	1.51	25000	32	**86**	287	25600	120	1230	500	4.1	**3000**	<0.3	61	41	217
	5-10 cm	23600	<0.4	7.9	165	1.1	2.19	26600	31	**88**	**305**	27500	107	1350	528	4.1	**2770**	<0.3	53	44	214
	10-20 cm	28000	<0.4	30.5	213	**1.4**	1.80	28800	41	**151**	**653**	54500	150	1370	670	4.9	**10400**	1.50	60	49	415
2292585 (Back yard)	0-5 cm	15700	<0.4	5.7	111	0.8	1.00	22700	29	39	191	21000	100	8710	347	4.5	**1820**	<0.3	81	30	214
	5-10 cm	18500	<0.4	7.8	128	1	1.11	27200	25	49	236	24000	113	1150	400	4.2	**2100**	<0.3	88	36	250
	10-20 cm	20900	<0.4	12.8	142	1	1.14	35500	28	**64**	**489**	29600	152	1750	494	4.4	**4030**	<0.3	88	39	283
2292587 (Front yard)	0-5 cm	38300	<0.4	1.8	305	**1.7**	1.87	36000	54	47	153	35900	**371**	1470	661	4.3	**1240**	<0.3	118	64	416
	5-10 cm	40500	<0.4	6.8	514	**1.8**	3.78	37900	53	**109**	**809**	40100	**552**	1630	681	4.9	**3470**	<0.3	133	69	**931**
	10-20 cm	41200	<0.4	7.1	345	**1.8**	1.73	51800	49	**82**	**415**	41400	**216**	1980	646	4.7	**2950**	<0.3	431	69	415

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2292588 (Back yard)	0-5 cm	34000	<0.4	1.4	193	1.5	0.57	33900	38	30	103	31700	98	1640	576	4.3	873	<0.3	101	57	160
	5-10 cm	37300	<0.4	2.5	205	1.6	0.54	34400	39	29	91	34900	118	1580	746	4.1	675	<0.3	114	61	195
	10-20 cm	45800	<0.4	0.3	278	2	0.75	40800	67	27	60	40200	103	1730	788	4.5	373	<0.3	120	73	146
2292589 (Front yard)	0-5 cm	30100	<0.4	3.0	201	1.3	0.61	52500	34	35	96	29600	104	2160	574	4.5	910	<0.3	144	52	175
	5-10 cm	36700	<0.4	0.6	202	1.6	0.43	53600	39	20	54	33800	49	2100	585	4.1	201	<0.3	126	60	156
	10-20 cm	34200	<0.4	1.3	228	1.5	0.65	37900	38	48	129	38600	97	1840	806	4.1	1540	<0.3	102	57	161
2292590 (Back yard)	0-5 cm	29800	<0.4	2.0	176	1.3	0.46	45500	32	21	69	29500	55	2190	516	4.4	357	<0.3	94	50	117
	5-10 cm	34400	<0.4	1.6	192	1.5	0.75	35800	38	22	108	31600	61	1920	452	4.1	380	<0.3	84	56	111
	10-20 cm	31900	<0.4	5.0	188	1.3	0.58	33000	37	32	134	29600	116	1860	487	4.1	1310	<0.3	75	52	159
2292591 (Front yard)	0-5 cm	16600	<0.4	17.8	220	1	2.25	27600	37	222	646	34300	237	1340	598	4.9	9760	3.90	63	41	747
	5-10 cm	29000	<0.4	16.1	272	1.4	1.76	35100	41	136	504	41100	203	1520	618	4.7	6640	0.30	83	55	580
	10-20 cm*	19975	1.4	27.1	204	1	1.55	26300	35	144	658	47625	222	1082	559	2.2	11825	2.08	63	48	473
2292592 (Back yard)	0-5 cm	33900	<0.4	11.5	353	1.6	1.28	24700	44	85	339	44100	250	1300	773	4.7	4740	<0.3	95	60	431
	5-10 cm	38400	<0.4	13.3	319	1.9	1.24	14900	47	80	329	43000	249	1070	461	4.4	5350	<0.3	98	67	353
	10-20 cm	47300	<0.4	8.3	294	2.1	0.58	17600	52	49	193	50800	94	1440	840	4.0	2610	<0.3	85	75	194
2292593 (Front yard)	0-5 cm	26400	<0.4	15.3	340	1.3	2.02	18800	41	144	452	42400	238	9330	641	4.4	6430	0.80	65	54	539
	0-5 cm	26700	<0.4	12.9	284	1.3	1.66	23100	40	159	428	42600	274	9990	710	4.3	5860	1.00	74	51	514
	0-5 cm	29700	<0.4	11	268	1	1.34	21000	41	129	325	40800	262	1020	636	4	4390	<0.3	72	57	418
	5-10 cm	26900	<0.4	15.5	349	1.3	1.55	22600	41	87	393	40900	231	9960	603	4.8	5110	<0.3	84	52	497
	5-10 cm	24700	<0.4	24.1	449	1.2	2.95	24800	50	146	722	55000	420	9700	716	5.3	9030	2.60	82	49	936
	5-10 cm	30500	<0.4	14.6	370	1.4	2.34	22800	47	82	398	42600	326	1120	600	4.3	4340	<0.3	71	57	648
	10-20 cm*	23800	4.5	45.2	517	1.4	35.33	23313	50	159	890	56050	771	8583	712	3.0	12350	4.78	105	51	945
	10-20 cm	26400	<0.4	27.2	512	1.4	3.31	22700	52	121	653	48600	553	9040	624	5.3	8530	2.20	102	51	960
	10-20 cm	39600	<0.4	5	290	2	1.17	29500	47	38	144	39500	170	1360	720	4	1420	<0.3	87	66	300
2292594 (Back yard)	0-5 cm	15000	<0.4	23.8	452	1	2.62	21500	42	172	640	38600	603	7530	542	4.8	8470	6.40	93	37	1020
	0-5 cm	15800	<0.4	26.0	440	1.2	2.56	21300	43	163	645	39700	614	6790	539	5.1	7940	5.00	121	38	1060
	0-5 cm*	15025	1.6	30.5	323	1	1.54	20350	37	177	632	39575	427	6530	590	2.5	8473	5.13	98	39	769
	5-10 cm*	15675	2.1	43.0	417	1	1.73	22350	40	144	776	47450	674	7795	545	2.7	10950	6.25	96	37	1230
	5-10 cm	18000	<0.4	35.6	464	1.3	3.33	21300	44	171	823	52100	750	6570	561	5.2	13400	5.80	127	37	1160
	5-10 cm*	18325	1.0	36.0	375	1.1	1.91	19900	41	139	772	48800	582	7550	622	3.4	10650	5.61	93	39	981
	10-20 cm*	14675	1.5	29.7	329	1	1.94	22925	39	86	526	45975	549	6853	498	4.1	6855	3.78	107	34	1075
	10-20 cm*	17775	1.1	26.6	342	1	1.61	21975	36	86	629	40450	512	6600	466	3.3	7448	3.76	112	38	849
	10-20 cm*	17950	0.9	32.9	348	1.1	1.60	22125	37	102	605	44075	546	7010	532	3.5	8540	4.00	115	37	866

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Site / Location	Soil Depth	Al	Sb	As	Ba	Be	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	Sr	V	Zn
2292595 (Front yard)	0-5 cm*	13200	0.4	6.3	85	0.6	0.47	7518	18	33	103	17975	78	4195	417	2.1	1213	0.66	31	31	150
	5-10 cm	14900	<0.4	10.4	174	0.9	0.86	13700	25	54	233	23300	199	5710	435	3.8	2730	<0.3	64	34	300
	10-20 cm	12500	<0.4	12.0	143	0.8	0.71	23000	25	50	262	21500	167	6890	353	3.9	3170	0.60	72	29	283
2292596 (Back yard)	0-5 cm	14600	<0.4	2.9	93	0.8	0.24	26800	18	52	66	16300	37	1050	373	3.8	550	<0.3	75	33	135
	5-10 cm	15400	<0.4	2.3	94	0.9	0.23	30200	18	37	61	16700	37	1130	367	3.7	547	<0.3	84	34	104
	10-20 cm	14100	<0.4	4	94	1	0.24	34000	19	60	68	16100	39	1200	406	4	675	<0.3	96	34	100
2292597 (Front yard)	0-5 cm	19000	<0.4	13.5	235	1.2	1.67	19900	40	63	301	33100	409	6720	508	4.6	3460	0.60	95	37	539
	5-10 cm	19800	1.0	16.9	245	1.4	1.78	21500	40	64	328	33900	368	6860	540	4.5	3590	0.70	106	38	530
	10-20 cm	16800	<0.4	24.2	256	1.5	2.14	22200	39	85	428	42000	363	6220	566	5.3	5940	2.43	143	35	587
2292598 (Back yard)	0-5 cm	12300	0.8	9.7	138	0.7	1.72	14300	45	46	180	21500	210	4920	303	3.9	2190	0.40	60	26	323
	5-10 cm	12900	1.7	13.6	158	0.8	1.86	17700	44	51	207	20600	364	5330	326	4.1	2440	0.64	67	27	336
	10-20 cm	12500	0.7	16.3	213	1.2	1.79	18800	36	56	257	22300	289	5160	335	4.4	3000	0.70	145	28	400
2292599 (Front yard)	0-5 cm	13800	<0.4	8.1	87	0.6	0.99	11800	21	43	156	22500	111	5730	406	3.6	2140	<0.3	34	28	245
	5-10 cm*	13850	0.4	10.6	79	0.5	0.78	9158	20	40	151	20825	93	4440	367	2.3	1963	0.60	28	29	214
	10-20 cm	14600	<0.4	10.9	77	0.7	1.04	8890	23	48	212	25400	98	4340	403	3.5	2990	0.30	29	27	235
2292600 (Back yard)	0-5 cm	13300	<0.4	7.8	75	0.5	0.96	6900	25	41	138	17600	118	3250	258	3.1	1750	<0.3	33	27	268
	5-10 cm	13600	<0.4	3.8	48	0.5	0.56	3970	16	21	67	15000	58	2400	200	2.6	837	0.30	24	26	129
	10-20 cm	14100	6.4	6.7	71	0.6	1.10	4930	20	36	135	20800	101	2770	273	3.0	1540	<0.3	24	26	205
2292601 (Front yard)	0-5 cm	4580	<0.4	1.3	22	0.2	0.18	18000	8	5	8	8820	8	5380	240	3.2	48	<0.3	34	16	30
	5-10 cm	4880	<0.4	2.7	19	0.3	0.18	19400	9	5	6	10100	6	5480	236	3.3	38	<0.3	37	19	23
	10-20 cm	32100	0.7		134	1.2	0.18	6520	40	16	8	27100	35	8050	220	3.3	38	<0.3	73	63	74
2292602 (Back yard)	0-5 cm	5970	<0.4	4.1	61	0.3	0.71	19100	13	30	99	12400	74	5960	286	3.6	1040	<0.3	60	20	195
	5-10 cm	12900	0.7	22.5	304	0.8	2.82	19100	31	85	486	37100	334	6430	465	4.5	6240	4.90	81	30	990
	10-20 cm	18600	0.7	28.3	230	1.1	2.81	32000	33	80	2720	41000	355	8820	474	5.1	7410	3.78	113	36	1210
2292603 (Front yard)	0-5 cm	24700	<0.4	12.2	191	1.2	1.53	16100	32	58	264	27700	146	7860	430	4.5	2860	0.69	72	45	310
	5-10 cm	26600	<0.4	11.2	185	1.3	1.41	13900	33	50	236	27300	115	7570	405	4.3	2560	<0.3	68	47	260
	10-20 cm	18000	<0.4	30.3	221	1.1	2.23	15700	38	101	612	48500	206	6740	682	5.0	7920	3.90	69	34	546
2292604 (Back yard)	0-5 cm	5630	<0.4	4.1	39	0.3	0.43	20000	11	13	39	11500	43	6580	249	3.7	419	<0.3	54	21	82
	5-10 cm	6580	0.4	9.5	95	0.5	0.96	17800	14	30	136	14800	163	5230	280	4.0	1500	0.56	81	20	232
	10-20 cm	17400	6.8	41.2	533	1.8	4.31	19700	49	153	791	60200	1800	5700	722	6.2	10300	5.75	190	38	1350

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2292605 (Front yard)	0-5 cm	16700	<0.4	20.2	232	1	2.53	35500	35	90	491	37200	389	1620	622	5.7	5700	2.80	124	34	667
	0-5 cm	18100	<0.4	18.1	254	1.1	2.71	28400	35	81	444	35700	327	1280	599	5.4	4890	2.66	114	36	620
	0-5 cm	15500	<0.4	20.9	206	0.9	2.83	26300	34	88	502	37400	351	1190	593	5.2	5780	3.11	95	32	662
	5-10 cm	21500	<0.4	34.1	235	1.2	3.33	22700	44	138	739	57400	372	1020	799	6.7	9570	4.01	89	40	766
	5-10 cm	21200	<0.4	25.5	240	1.3	2.58	24600	37	113	610	48100	313	1070	718	5.3	7820	2.90	91	40	740
	5-10 cm	19300	<0.4	33.2	218	1.2	3.22	20800	40	145	799	58000	376	9520	818	5.4	9520	4.98	85	36	844
	10-20 cm	18000	<0.4	40.8	265	1.2	3.37	24900	38	134	888	59400	392	9040	836	6.0	10800	5.03	90	32	794
	10-20 cm	18000	<0.4	31.9	216	1.2	2.74	24300	35	113	716	48000	306	9540	719	5.3	8160	3.47	89	36	758
	10-20 cm	18100	<0.4	28.0	212	1.1	3.04	22700	34	107	654	48200	333	9670	725	5.3	8230	3.81	94	35	686
2292606 (Back yard)	0-5 cm	19000	<0.4	16.7	250	1.1	1.92	25700	34	88	391	36500	284	1020	1280	5.8	4230	2.20	134	36	519
	0-5 cm	20000	0.5	18.8	194	1.2	1.84	13700	35	96	392	35400	196	6800	680	4.7	4710	2.76	91	43	433
	0-5 cm	21400	0.8	22.3	241	1.3	3.01	14700	39	101	447	36800	269	6230	702	5.0	4910	3.42	114	43	537
	5-10 cm	22300	3.1	22.0	307	1.2	2.54	13500	46	96	465	45200	408	6480	671	5.1	5700	2.79	82	42	666
	5-10 cm	26500	0.5	24.5	224	1.4	1.97	14300	43	100	504	48900	220	7660	750	4.8	6450	1.98	78	45	548
	5-10 cm	23100	1.2	24.8	253	1.4	2.33	13700	43	113	554	50200	241	6500	964	5.1	7110	2.51	103	42	604
	10-20 cm	22400	1.9	29.0	252	1.3	2.38	16400	46	113	559	53900	320	7430	766	5.4	7830	3.72	87	41	689
	10-20 cm	27700	0.6	33.4	267	1.5	2.17	19600	49	99	541	53700	252	9160	847	5.1	7690	3.00	99	47	583
	10-20 cm	23300	0.4	32.1	271	1.5	2.24	17500	46	113	567	55500	309	7560	836	5.6	8190	3.76	120	42	599
2292608 (Back yard)	0-5 cm	13500	<0.4	19.0	131	0.8	1.88	15100	27	90	339	35100	185	5410	628	4.6	4140	2.66	60	27	450
	5-10 cm	12600	0.6	24.7	119	0.7	1.93	16000	30	90	378	42900	88	5180	715	4.5	4780	2.11	56	25	442
	10-20 cm	12900	0.7	20.5	102	0.7	1.73	16800	25	73	338	35500	157	5370	591	4.6	4560	1.34	56	26	364
2292609 (Back yard)	0-5 cm	22900	<0.4	2.9	125	1	0.54	7170	30	23	68	22900	58	5840	415	3.4	670	<0.3	66	41	140
	5-10 cm	28800	<0.4	1.1	143	1.2	0.43	5680	33	20	44	26600	47	6690	433	3.1	392	<0.3	37	50	106
	10-20 cm	36200	<0.4	1.9	177	1.5	0.47	6640	42	23	47	33700	54	8330	500	3.7	390	<0.3	52	61	124
2292610 (Front yard)	0-5 cm	14800	<0.4	6.0	100	0.5	0.51	6390	17	23	69	16300	73	3380	241	6.3	685	<0.3	25	25	152
	5-10 cm	14700	<0.4	5.5	94	0.4	0.44	5250	17	22	62	14500	61	3050	237	6.2	708	<0.3	21	25	123
	10-20 cm	16600	0.4	11.0	135	0.6	0.76	8280	22	36	156	21800	122	4630	390	8.2	1490	<0.3	30	30	217
2292611 (Back yard)	0-5 cm	16400	0.5	9.9	146	0.6	0.90	8910	22	30	110	22700	123	4920	482	8.3	808	<0.3	33	30	232
	5-10 cm	17700	<0.4	11.0	161	0.7	0.86	10100	24	32	109	23400	129	5500	491	8.8	820	<0.3	36	32	246
	10-20 cm	18600	1.2	13.2	180	0.8	1.29	14900	30	40	153	27700	190	6590	487	10.3	1190	<0.3	51	35	341
2292612 (Front yard)	0-5 cm	17100	0.7	12.2	141	0.8	0.75	23400	26	47	144	27200	137	1210	547	10.6	1380	<0.3	57	35	233
	5-10 cm	19300	0.9	12.5	150	1	0.79	28600	29	48	150	29700	137	1580	626	11.8	1370	<0.3	66	37	238
	10-20 cm	19300	0.8	12.0	132	0.9	0.73	29100	29	47	144	31500	101	1520	678	11.7	1470	<0.3	60	36	203

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2292613 (Back yard)	0-5 cm	20700	0.9	10.5	158	1	0.98	21100	30	40	123	27400	118	1140	556	11.0	**1030**	<0.3	54	39	222
	5-10 cm	21700	0.9	9.8	159	1	0.95	28600	29	40	115	28200	112	1520	593	11.6	**936**	<0.3	61	40	210
	10-20 cm	23500	0.5	9.6	150	1	0.78	33200	31	39	100	29800	79	1630	630	12.1	**835**	<0.3	66	42	166
2292614 (Side yard)	0-5 cm	17500	1.4	17.4	131	0.9	0.87	19900	27	**56**	210	30600	116	8560	512	10.6	**2270**	1.00	59	34	218
	5-10 cm	21700	1.1	17.8	151	1	0.77	24500	33	**57**	202	32600	108	1010	548	11.8	**2080**	<0.3	64	41	211
	10-20 cm	21300	1.5	17.8	154	1	0.96	20600	30	**57**	210	34000	121	8720	599	11.6	**2190**	0.80	67	39	216
2292615 (Front yard)	0-5 cm	13600	<0.4	7.6	95	0.6	3.13	16900	25	25	58	18800	105	7920	488	8.1	**430**	<0.3	51	31	140
	0-5 cm	13500	<0.4	5.8	95	0.5	0.94	19600	21	24	56	17200	83	8780	434	7.9	**418**	<0.3	50	30	124
	0-5 cm	16500	1.1	6.9	125	0.7	1.33	18300	26	29	67	21500	97	9370	501	9.2	**503**	<0.3	62	35	159
	5-10 cm	14000	<0.4	5.6	98	0.6	0.78	20200	21	25	49	19300	73	8550	491	8.4	**330**	<0.3	55	32	119
	5-10 cm	10700	<0.4	3.6	63	0.4	0.43	18900	17	19	37	14500	55	9010	316	7.0	**277**	<0.3	45	28	85
	5-20 cm	13500	<0.4	6.3	98	0.6	0.84	17500	21	25	60	19200	83	8460	471	8.2	**412**	<0.3	69	31	133
	10-20 cm	19900	0.5	7.6	139	0.9	0.75	22700	28	31	60	25100	75	9160	621	10.3	**406**	<0.3	79	40	136
	10-20 cm	17500	<0.4	7.1	123	0.8	0.61	22500	26	28	60	22200	93	1040	474	9.7	**402**	<0.3	78	38	147
	10-20 cm	22900	0.5	7.1	147	1	0.83	15400	31	33	60	27200	77	9950	679	10.8	**412**	<0.3	64	45	133
2292616 (Back yard)	0-5 cm	11000	<0.4	6.5	76	0.4	1.26	13700	18	22	59	15800	103	6280	467	7.0	**352**	<0.3	36	26	134
	0-5 cm	13300	<0.4	7.7	96	0.5	0.77	12000	20	25	68	17900	119	6300	521	7.7	**396**	<0.3	40	29	164
	0-5 cm	12600	0.4	7.6	79	0.4	0.81	13400	18	24	67	16500	111	6530	481	7.2	**418**	<0.3	37	27	162
	5-10 cm	9880	<0.4	6.9	78	0.4	0.88	20500	15	23	72	15500	116	7740	361	7.1	**446**	<0.3	51	25	161
	5-10 cm	11600	<0.4	6.3	86	0.4	0.91	15200	16	22	61	16400	145	7250	460	7.2	**351**	<0.3	41	26	175
	5-10 cm	11100	0.4	6.6	74	0.4	1.26	15600	15	24	68	15600	123	7180	394	7.1	**426**	<0.3	40	25	282
	10-20 cm	11300	0.6	7.6	98	0.4	0.87	22700	18	27	88	18500	140	9150	379	8.0	**582**	<0.3	66	29	192
	10-20 cm	12600	<0.4	6.9	113	0.5	1.03	19800	18	26	76	17400	131	8690	423	7.9	**479**	<0.3	71	27	246
	10-20 cm	8070	<0.4	5.2	56	0.3	1.39	16800	13	21	54	13600	95	7390	271	6.5	**364**	<0.3	38	23	408
2292617 (Front yard)	0-5 cm	16900	1.4	16.4	177	0.9	1.43	24200	31	**57**	238	29700	**316**	1040	615	11.7	**1920**	0.60	84	34	361
	5-10 cm	17900	<0.4	15.3	158	1.1	1.72	19200	36	50	259	33700	**251**	8440	646	4.7	**2630**	1.40	70	36	401
	10-20 cm	19800	<0.4	15.7	160	1.2	1.56	19200	32	46	251	32900	196	8930	638	4.6	**2430**	0.90	65	37	316
2292618 (Front yard)	0-5 cm	13900	<0.4	2.4	83	0.7	0.66	26700	24	13	43	19100	64	1010	487	4.4	107	<0.3	60	28	131
	5-10 cm	15700	<0.4	2.3	94	0.8	0.56	29500	32	16	42	21500	67	1000	567	4.7	101	<0.3	67	31	117
	10-20 cm	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
2292619 (Back yard)	0-5 cm	13500	<0.4	2.7	79	0.7	0.72	27200	23	14	47	18700	69	1030	519	4.3	196	<0.3	56	27	132
	5-10 cm	13900	<0.4	4.1	82	0.7	0.69	30800	21	12	37	19000	51	1110	514	4.3	97	<0.3	61	29	112

Table A1: Chemical analysis of soils collected in the fall of 2000

Site / Location	Soil Depth	Al	Sb	As	Ba	Be	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	Sr	V	Zn
2292620 (Front yard)	0-5 cm	10100	<0.4	5.8	149	0.6	1.16	18400	25	22	81	21300	254	7560	582	4.2	985	<0.3	42	25	267
	5-10 cm	10900	0.4	4.8	167	0.6	1.07	14400	26	18	64	21200	324	6590	605	3.8	591	<0.3	33	25	233
	10-20 cm	10900	3.6	15.9	389	0.9	2.36	24000	43	64	290	43100	769	9070	680	5.3	5940	0.80	82	24	591
2292621 (Back yard)	0-5 cm	15900	<0.4	4.1	87	0.8	0.47	20000	22	14	45	18000	82	1010	362	3.9	298	<0.3	35	32	135
	5-10 cm	17700	<0.4	2.4	96	0.8	0.44	24400	23	13	38	19000	77	1120	377	4.1	228	<0.3	36	34	127
	10-20 cm	20500	<0.4	2.3	98	1	0.39	17900	25	12	31	21900	40	8760	440	3.7	184	<0.3	31	39	100
2292622 (Front yard)	0-5 cm	18400	0.7	3.8	111	1	0.65	19500	26	19	77	21900	115	1060	443	4.3	450	<0.3	42	34	173
	5-10 cm	19400	<0.4	4.3	117	1	0.58	21100	28	18	61	22200	92	1160	544	4.1	367	<0.3	40	36	145
2292623 (Back yard)	0-5 cm	15400	<0.4	3.4	90	0.8	0.58	15400	22	16	53	18300	97	7800	349	3.8	341	<0.3	33	31	163
	5-10 cm	15400	<0.4	4.4	96	0.8	0.66	16700	22	16	55	18400	122	7960	348	3.8	381		35	32	186
	10-20 cm	9150	<0.4	2.5	55	0.5	0.39	22900	14	10	31	12700	96	7340	266	3.8	199	<0.3	35	22	119
2292624 (Front yard)	0-5 cm	23000	6.1	22.0	208	1.3	2.13	27600	37	70	383	41400	332	9140	687	5.2	4100	2.40	85	40	427
	5-10 cm	25200	5.8	22.9	220	1.4	2.01	30000	34	61	347	41900	286	9260	680	4.8	4010	2.30	89	42	377
	10-20 cm	21900	6.0	19.9	213	1.3	1.86	32800	28	53	334	37800	279	8220	651	4.9	3800	2.10	102	37	359
2292625 (Back yard)	0-5 cm	29100	5.1	18.6	234	1.3	2.18	26400	38	41	190	34700	289	1230	626	4.8	1750	<0.3	133	49	330
	5-10 cm	31000	5.6	17.1	230	1.3	1.35	29600	39	38	221	35900	302	1360	687	4.7	1580	<0.3	146	51	287
	10-20 cm	32700	6.2	12.0	249	1.5	1.48	29500	39	44	197	37000	212	1320	617	5.0	1730	<0.3	160	53	299
2292626 (Side yard)	0-5 cm	21600	5.2	12.9	174	1	1.16	17700	29	37	162	26400	197	8470	403	4.1	1610	0.40	77	38	222
	5-10 cm	27300	5.5	14.9	213	1.2	1.36	21400	35	47	203	33500	254	1020	488	4.7	2090	0.40	95	46	273
	10-20 cm	24700	5.5	20.6	218	1.2	1.60	24200	34	48	218	31100	290	1000	440	4.5	2190	0.90	126	43	299
2292627 (Front yard)	0-5 cm	21600	5.6	15.9	189	1	1.44	20500	33	76	296	32300	263	9080	470	4.8	2850	1.10	82	39	332
	5-10 cm	21900	5.5	20.5	172	1.1	1.51	19400	30	62	275	31200	179	7280	416	4.4	2890	2.40	84	39	262
	10-20 cm	30400	5.9	18.9	205	1.4	1.60	21000	38	64	302	40100	160	8760	540	4.7	3480	1.60	92	52	278
2292628 (Back yard)	0-5 cm	22100	4.7	13.2	178	1.1	1.30	25500	35	54	237	31200	198	1120	554	4.8	2400	0.90	108	42	325
	5-10 cm	31600	5.0	7.9	192	1.3	0.83	15100	39	36	144	31600	124	9300	561	4.4	1450	<0.3	73	53	238
	10-20 cm	22700	6.5	10.1	149	1	0.85	25800	36	35	180	29900	146	1020	954	5.1	1870	0.60	73	38	342
2292629 (Front yard)	0-5 cm	17500	4.6	28.2	200	1.1	2.47	19000	35	193	676	43900	291	7370	766	5.1	7870	8.60	81	38	592
	0-5 cm	13300	5.4	36.1	204	0.9	2.91	16200	43	209	780	65800	373	5960	865	5.9	10600	10.00	64	32	794
	0-5 cm	12000	6.2	30.8	195	0.9	2.73	16500	36	181	674	53300	407	5810	758	5.2	9460	9.90	65	30	733
	5-10 cm	16500	5.7	42.6	197	1	3.03	14100	37	150	734	55800	345	5610	760	4.9	9860	8.50	57	31	721
	5-10 cm	17600	6.5	57.8	254	1.2	4.30	17300	53	262	1100	83300	459	6350	1050	6.4	15600	19.40	71	31	1150
	5-10 cm	15700	6.1	44.6	253	1.1	3.57	15700	47	218	949	71000	421	5770	876	5.9	13100	14.20	66	32	934
	10-20 cm	19300	5.5	29.4	172	1.1	2.03	15700	29	75	450	38300	211	5670	572	4.2	5720	4.30	60	40	399
	10-20 cm	13600	4.5	11.0	101	0.8	0.85	11200	22	34	182	29700	92	4930	353	3.4	2600	0.90	37	41	188

Table A1: Chemical analysis of soils collected in the fall of 2000

Site / Location	Soil Depth	Al	Sb	As	Ba	Be	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	Sr	V	Zn
	10-20 cm	10700	4.3	18.2	109	0.7	1.52	12200	22	62	304	33900	185	4990	441	4.0	4330	3.80	39	31	348
2292630 (Back yard)	0-5 cm	14600	4.5	10.1	141	0.8	1.33	20900	23	36	163	24800	156	6850	457	4.2	1650	0.80	63	29	349
	0-5 cm	10300	4.5	8.2	121	0.6	1.16	22400	21	32	129	21500	188	7510	334	4.0	1410	0.80	59	24	322
	0-5 cm	13300	6.0	10.9	164	0.8	1.66	22300	25	39	172	23200	244	7870	401	4.3	1580	1.00	75	27	447
	5-10 cm	15900	6.0	17.1	264	1	1.92	24900	28	44	257	31900	351	7540	443	4.6	2750	2.70	87	30	615
	5-10 cm	15700	7.5	22.4	295	1.1	2.78	27700	33	61	402	38500	448	8190	533	4.8	3780	2.40	117	31	751
	5-10 cm	13600	6.1	14.8	182	0.9	1.89	26200	27	51	246	32000	298	8220	435	4.0	2720	1.90	79	30	492
	10-20 cm	19600	6.1	23.1	219	1.2	2.11	31200	31	44	274	35300	252	1010	526	4.7	2800	1.80	101	37	492
	10-20 cm	17400	8.3	21.9	281	1.2	2.12	29400	32	55	337	39800	612	8150	545	4.8	3830	1.80	126	32	625
	10-20 cm	19300	6.6	23.7	383	1.6	2.35	31800	34	48	358	37700	498	8320	548	4.8	3200	1.50	165	37	692
2292631 (Front yard)	0-5 cm	20800	4.0	5.4	88	0.7	0.52	4960	23	22	70	21100	63	3970	311	3.0	914	<0.3	24	35	123
	5-10 cm	20800	3.5	5.7	89	0.7	0.56	5840	23	22	75	22000	63	4280	329	3.3	927	<0.3	23	36	125
	10-20 cm	23100	4.4	13.0	137	1	0.96	12000	30	36	164	28800	113	6120	423	4.0	2120	1.10	38	40	197
2292632 (Back yard)	0-5 cm	37700	4.6	2.9	171	1.3	0.64	8990	39	21	67	27200	84	6940	306	3.6	545	<0.3	51	55	152
	5-10 cm	27800	<0.4	8.7	174	1.2	0.98	11900	37	32	118	28900	125	7080	379	3.8	1140	<0.3	55	51	228
	10-20 cm	20000	5.3	17.7	164	0.9	1.47	15900	30	45	200	32100	200	6840	487	4.1	2290	0.60	59	37	295
2292633 (Front yard)	0-5 cm	26300	4.4	8.5	187	1.2	1.12	14600	33	36	160	28600	190	6580	451	4.1	1710	<0.3	59	45	272
	5-10 cm	28200	5.0	10.4	225	1.3	1.26	15900	35	41	190	32300	226	7470	529	4.2	2170	<0.3	63	47	307
	10-20 cm	28800	5.7	11.7	220	1.3	1.23	31300	34	39	212	35400	202	1050	587	4.7	2450	<0.3	85	47	305
2292634 (Back yard)	0-5 cm	28000	4.6	8.3	182	1.2	1.24	12100	35	40	170	30900	276	6490	558	4.0	1740	<0.3	45	48	304
	5-10 cm	27600	5.3	6.2	165	1.2	0.95	10400	32	33	139	28500	150	6570	539	3.7	1450	<0.3	38	46	224
	10-20 cm	30000	5.7	9.5	208	1.4	1.09	23100	41	40	208	34400	190	1050	5620	5.1	2040	<0.3	60	53	288
2292635 (Front yard)	0-5 cm	30000	5.5	8.0	180	1.3	1.14	14000	35	41	172	34200	132	7780	525	4.1	1990	<0.3	53	50	240
	5-10 cm	30900	5.1	8.9	187	1.3	1.06	13500	35	38	172	34300	134	7910	548	4.2	2030	<0.3	52	51	221
	10-20 cm	31200	5.6	11.1	212	1.4	1.12	22600	39	44	225	38900	160	9880	597	4.8	2790	<0.3	65	51	260
2292636 (Front yard)	0-5 cm	19000	5.2	13.8	151	0.8	1.17	23800	27	45	225	31400	198	1080	490	4.6	3030	0.80	58	34	321
	5-10 cm	17800	5.2	15.2	143	0.8	1.15	27300	26	46	229	32600	192	1160	540	4.6	3140	1.10	61	32	302
	10-20 cm	17700	5	17	151	1	1.32	35600	27	51	259	35000	181	1410	604	5	3590	1	68	32	321
2292637 (Front yard)	0-5 cm	21600	5.1	14.5	188	1	1.64	16700	35	63	267	39100	248	8270	607	4.5	3830	1.30	56	38	418
	5-10 cm	20400	6.6	27.1	203	1	2.16	16300	37	85	385	49500	302	7780	688	4.7	6420	3.60	49	34	521
	10-20 cm	20300	6.1	19.4	186	1	1.58	14900	31	54	254	35900	223	7010	562	4.3	3650	1.40	47	37	341
2292638 (Back yard)	0-5 cm	17500	5.4	12.3	175	0.9	1.14	19800	31	47	205	35700	263	8210	521	4.5	2850	0.80	66	36	352
	5-10 cm	24100	8	15	232	1	1.22	21900	36	50	287	39500	428	9310	598	5	2810	0	81	44	374
	10-20 cm	24300	6.8	13.0	272	1.2	1.14	21500	36	43	207	37600	406	8510	491	4.4	2630	0.40	89	43	404

Table A1: Chemical analysis of soils collected in the fall of 2000

Site / Location	Soil Depth	Al	Sb	As	Ba	Be	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	Sr	V	Zn
2292640 (Back yard)	0-5 cm	15300	<0.4	1.7	65	0.6	0.72	4990	17	17	51	14700	53	3120	226	2.7	<u>420</u>	<0.3	19	30	113
	5-10 cm	15700	<0.4	3.0	63	0.6	0.55	4380	16	17	47	14600	48	3050	224	2.6	<u>429</u>	<0.3	18	30	99
	10-20 cm	17800	<0.4	5.2	89	0.8	0.69	7890	22	25	85	17900	79	4710	341	3.3	<u>779</u>	<0.3	28	35	139

Table A2: Results of Chemical Analysis of Trench Soil Samples, Port Colborne, Fall 2000

Site/Location	Soil Depth	Al	Sb	As	Ba	Be	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	Sr	V	Zn
2292641	30 - 35 cm	25500	1.6	8.5	222	**1.26**	0.025	53100	31.5	29.3	182	27900	76	20400	455	2.3	**1500**	<0.3	246	48.9	156
Baseball Park, SE	30 - 35 cm	19700	1.3	9.3	160	0.98	0.025	55700	24.5	28.7	191	24400	77	22900	499	2.2	**1430**	<0.3	282	40.5	154
corner of Davis &	60 - 65 cm	24600	1.3	8.7	240	**1.38**	0.025	74000	26.6	29.3	188	27000	82	23900	668	2.3	**1740**	<0.3	292	45.4	132
Rodney Sts., near	60 - 65 cm	24300	2	9	205	**1.31**	0.05	67700	33.5	28.6	158	29400	77	22800	568	2.6	**1540**	<0.3	215	48.8	137
2nd base	100 - 105 cm	12100	2.5	**33.1**	84.7	0.4	0.025	16100	24.3	**88.8**	**524**	38400	127	4660	377	2.5	**6680**	2.5	68.1	30.9	341
	100 - 105 cm	24100	1.6	12.5	179	**1.23**	0.025	48100	29.9	**50.5**	**440**	29600	86	18300	517	2.4	**3020**	<0.3	190	48.5	166
2292642	30 - 35 cm	22400	1.4	9.9	207	**1.25**	0.025	70200	27.5	26.6	148	26600	67	29700	408	2.5	**1500**	<0.3	336	48.1	128
Baseball Park, SE	30 - 35 cm	22500	1.1	8.2	320	1.4	0.12	84500	31.8	22.8	123	24200	63	31200	519	2.5	**1290**	<0.3	460	44	107
corner of Davis and	60 - 65 cm	22700	2.1	11.2	224	**1.35**	0.08	66200	28.2	26.8	135	29800	71	24600	601	2.6	**1430**	<0.3	263	46.5	119
Rodney Sts., centre	60 - 65 cm	18500	0.8	4.2	94.8	0.51	0.09	6320	24.5	10.8	37.1	16200	24	4440	198	1.1	**304**	<0.3	52.8	39.7	63
of outfield	100 - 105 cm	20500	1.6	15.8	224	**1.41**	0.025	62600	25	32	207	29600	99	23800	574	2.6	**2100**	<0.3	226	42.5	166
	100 - 105 cm	10700	0.5	13.6	72.8	0.28	0.025	11100	15.7	21.8	266	21400	29	4700	246	1.4	**2210**	<0.3	54	30.5	127
2292643	30 - 35 cm	12000	3.8	**37.4**	118	0.97	0.025	97600	38	177	**749**	53700	183	39100	690	3.5	**9730**	4.6	171	41.2	436
North shoulder of	30 - 35 cm	9020	2.9	**30.7**	149	0.77	0.025	106000	30	176	**699**	46900	148	49200	597	3.2	**8900**	4.8	130	36.2	334
Rodney St., between	60 - 65 cm	12900	7.2	**43.1**	309	2.1	3.34	18900	30.9	24.7	80.6	168000	**247**	4050	1920	4.6	**204**	<0.3	124	75.7	**3190**
Mitchell & Davis Sts.	60 - 65 cm	27000	6.5	19	525	**4.21**	2.3	84600	21.3	23.3	51.9	137000	150	10700	1400	2.7	**384**	<0.3	323	73	**3710**
	100 - 105 cm	20700	1.1	6.4	116	0.61	0.3	14600	25.1	10.5	48.4	17500	34	4840	191	1.6	**374**	<0.3	82.2	35.8	113
	100 - 105 cm	23900	0.8	2.5	121	0.67	0.13	5420	28.1	10.8	4.8	17100	28	5500	189	1	66.4	<0.3	39.5	42.1	81
2292644	30 - 35 cm	2520	0.2	6.9	18.7	0.05	0.24	27800	5.86	8.68	34.9	12500	25	7180	163	1.3	**364**	<0.3	41.7	14.1	81
NW corner of vacant	30 - 35 cm	3170	1.3	16.2	38	0.19	0.32	29800	15.6	29.8	158	33700	69	7340	316	2.2	**1650**	0.5	51.5	15.6	293
lot south of Rodney	60 - 65 cm	2700	0.2	2.6	23.9	0.06	0.21	30600	5.14	3.77	11.7	7780	18	7870	156	1.2	102	<0.3	62.6	12.5	34
St. between Welland	60 - 65 cm	3440	1.2	12.6	32.1	0.13	0.33	30400	17	24.4	115	31200	58	7940	333	2.4	**1310**	<0.3	46.6	22.6	218
& Fares Sts.	100 - 105 cm	2720	0.2	3.2	33.9	0.19	0.4	21600	6.13	4.2	9.6	6460	5	1260	233	3	96.9	<0.3	117	23.3	9
	100 - 105 cm	2870	0.2	4.3	47.2	0.16	0.29	25700	6.51	5.96	20.9	6930	5	1430	279	5.2	**210**	2.5	145	21.6	28
2292645	30 - 35 cm	3340	0.2	7.5	28.8	0.28	0.36	30700	6.88	6.08	47.6	14300	21	7030	222	5.3	**289**	<0.3	53.2	16.2	89
NE corner of vacant	30 - 35 cm	3780	0.2	**27.3**	68.1	0.39	1.94	29100	11.7	49	275	41300	123	6660	725	6.4	**3320**	0.9	55.6	9.1	409
lot south of Rodney	60 - 65 cm	2720	0.2	3.7	16.2	0.19	0.16	30100	6.64	3.83	16.2	8740	8	7590	161	5.4	91.7	<0.3	47.7	17.3	32
St. between Welland	60 - 65 cm	2480	0.2	2.3	12.4	0.15	0.1	14900	5.13	2.86	1.2	6100	5	6250	112	4.6	14.8	<0.3	28.1	13.1	13
& Fares Sts.	100 - 105 cm	1420	0.2	5	25.7	0.15	0.26	21800	4.04	5.51	17.9	6490	7	2090	152	4.1	185	<0.3	87	5.6	35
	100 - 105 cm	1440	0.2	3.9	23.7	0.14	0.2	22700	3.57	3.69	12.3	5710	3	2100	133	4	123	0.5	97.6	6.27	24
2292647	30 - 35 cm	20400	0.2	7.9	153	1.15	0.99	24900	39.8	24.6	107	37300	138	9100	623	7	**516**	<0.3	75.2	38.3	289
West trench in park	30 - 35 cm	7960	0.2	13.6	117	0.82	1.46	40900	54.1	29.7	167	56300	124	8780	1290	9.3	**975**	<0.3	96.9	13	499
E of Welland St & N	60 - 65 cm	12600	9.4	17.1	307	**2.49**	5.88	40300	122	**51.9**	141		**479**	3770	4050	12.8	**558**	1.4	157	1.28	**3410**
of Nickel St.	60 - 65 cm	10300	8	12.5	282	**2.11**	6.17	30500	94.2	**52.8**	151		**520**	3200	3990	10.6	**640**	0.8	126	0.74	**3680**
	100 - 105 cm	7070	0.2	14.6	121	0.86	1.18	37100	12.5	13.4	124	20900	97	2500	343	7.2	**739**	<0.3	469	21.7	173
	100 - 105 cm	4980	0.2	13.1	100	0.58	0.97	26100	9	12.2	85.8	14500	104	1780	247	6.4	**727**	<0.3	302	18.3	120

Table A2: Results of Chemical Analysis of Trench Soil Samples, Port Colborne, Fall 2000

Site/Location	Soil Depth	Al	Sb	As	Ba	Be	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	Sr	V	Zn
2292647	30 - 35 cm	8740	10.5	**32**	168	1.08	3.49	53400	110	47.2	134	15100	**335**	11500	3300	10.7	**613**	<0.3	224	34.4	**1870**
East trench in park	30 - 35 cm	13100	0.8	9.7	48.7	0.74	0.47	122000	27.8	15.3	58.5	18100	34	70400	227	3.3	**301**	<0.3	72.8	33.3	59
west of Welland St.	60 - 65 cm	10400	9.3	**27.6**	198	**1.35**	4.41	54100	101	47.3	132	147000	344	12800	3610	9.3	**578**	<0.3	199	33.7	**1860**
& N of Nickel St.	60 - 65 cm	10400	6.7	21.3	195	**1.38**	2.35	50100	55.9	46.2	128	129000	**234**	11000	2750	5.2	**852**	<0.3	189	34.2	**1380**
	100 - 105 cm	16600	0.7	3.6	68.5	0.49	0.28	10600	18.8	10.3	16.7	17200	34	5600	226	1.5	97.3	<0.3	26.3	33.1	76
	100 - 105 cm	15400	0.4	3.5	70.1	0.46	0.27	11600	18.7	10.5	16.9	17400	42	6020	242	1.5	107	<0.3	26.7	32.9	82
2292648	0-5 cm	16600	0.8	3.2	72.1	0.51	0.3	14500	19	10.2	16.2	18200	38	6860	254	1.6	89.2	<0.3	30.7	33.7	77
West berm in park	0-5 cm	15900	0.6	4	75.4	0.49	0.28	15500	18.2	10.1	16	17700	43	7020	312	1.5	90.4	<0.3	30.6	32.9	74
west of Welland St.	5-10 cm	17200	1.4	4.4	84.4	0.59	0.26	27000	21	11.3	15.7	20900	39	12000	367	1.7	92	<0.3	44.5	34.8	79
& N of Nickel St.	5-10 cm	20300	1.1	4.6	109	0.74	0.28	33200	23.2	12.8	16.4	23200	37	14100	479	1.7	89.2	<0.3	53.7	39.5	85
	10-15 cm	24100	1.4	5.3	126	0.92	0.36	30800	28.9	14.4	18.5	29000	41	13300	482	1.8	105	<0.3	65.2	45.9	130
	10-15 cm	16400	1	3.8	92.8	0.61	0.3	32700	21.7	12.2	17.3	21100	44	11900	374	1.8	107	<0.3	54.4	33.8	100
2292649	0-5 cm	14400	0.2	1.7	71.4	0.63	0.41	11600	19.2	10.8	21.6	17300	55	5630	257	4.9	108	<0.3	27.6	30.2	96
East berm in park	0-5 cm	14100	0.2	2.7	66.6	0.58	0.41	11200	17.4	10.9	21.3	16300	53	5550	248	4.9	115	<0.3	24.4	29.6	87
west of Welland St.	5-10 cm	16200	0.2	3.1	79.3	0.71	0.39	14700	20	11.4	18.3	19100	45	7130	304	5.5	102	<0.3	31.5	32.3	87
& N of Nickel St.	5-10 cm	14100	0.2	3.7	80.9	0.65	0.45	18100	19.5	11.1	21.1	18200	60	7590	307	5.5	117	<0.3	34.3	27.4	105
	10-15 cm	26800	0.2	2.4	173	**1.29**	0.44	30800	33.2	16.4	23.4	29200	106	15200	514	6.3	98.4	<0.3	62.9	48.7	118
	10-15 cm	18400	0.2	4.7	124	0.92	0.49	35800	25.4	14.4	30.3	23700	110	14000	496	6.4	135	<0.3	63	35.7	133
	15-20 cm	19000	0.2	2.8	124	0.94	0.45	33200	26.4	15.1	29.9	24600	87	13500	447	6.3	143	<0.3	65.9	37.8	131
	15-20 cm	25100	0.2	2.9	157	1.21	0.41	33200	31.6	16.6	22	30100	61	15100	585	6.4	95.2	<0.3	68.7	46.2	105

Bold face and underlined values exceed corresponding MOE Table A generic guideline for residential/parkland land use- medium/fine textured soil.

Table A3: Samples from Port Colborne submitted for pH in distilled water

Sample ID	Soil pH (Run 1)	Soil pH (Run 2)	Soil pH (Mean)	Soil depth (cm)	Site / Location
800	7.18	7.18	7.18	0-5	2292547
805	7.11	7.09	7.10	10-20	2292548
824	7.11	7.05	7.08	0-5	2292555
854	7.22	7.27	7.24	0-5	2292561
858	7.42	7.37	7.39	5-10	2292562
946	7.48	7.52	7.50	10-20	2292583
947	7.03	6.99	7.01	0-5	2292640
952	7.14	7.19	7.16	0-5	2292484
956	7.19	7.21	7.20	5-10	2292485
1019	7.42	7.37	7.39	10-20	2292502
1020	7.13	7.13	7.13	0-5	2292503
1059	7.01	7.03	7.02	0-5	2292516
1134	7.26	7.26	7.26	0-5	2292537
1139	7.29	7.32	7.30	10-20	2292538
1330	7.36	7.37	7.36	0-5	2292584
1334	7.25	7.35	7.30	5-10	2292585
1373	7.56	7.61	7.58	5-10	2292595
1375	7.51	7.51	7.51	0-5	2292596
1379	7.29	7.21	7.25	5-10	2292597
1381	7.09	7.10	7.09	0-5	2292598
3341	7.38	7.37	7.37	0-5	2292410
3346	7.61	7.70	7.65	10-20	2292411
3814	7.22	7.30	7.26	5-10	2292376
3816	6.89	6.88	6.88	0-5	2292377
3834	7.66	7.65	7.65	10-20	Rodney/Fares St
3892	7.11	7.09	7.10	0-5	2292473
5182	7.25	7.28	7.26	0-5	2292327
5187	7.76	7.75	7.75	10-20	2292328
5252	6.98	6.99	6.98	5-10	2292445
5313	7.58	7.63	7.60	10-20	2292449
5315	6.95	6.85	6.90	5-10	2292450
5361	7.23	7.24	7.23	5-10	2292321
5363	7.21	7.26	7.23	0-5	2292322
5390	7.28	7.31	7.29	0-5	2292470
5404	7.52	7.61	7.56	10-20	2292471
5407	7.36	7.38	7.37	10-20	2292471

Appendix A-4: Simulated Stomach Acid Leach Test Results

Aluminum (Al)				
Sample I.D.	Station I.D.	Soil Concentration (μg/g)	Leach Concentration (μg/g)	% Leach
C77340 - 1	2022013	5,500	101	1.84
C77340 - 2	2022013	5,800	105	1.81
C77349 - 1	2023301	10,000	126	1.26
C77349 - 2	2023301	10,000	109	1.09
C77351 - 1	2023501	11,000	117	1.06
C77351 - 2	2023501	12,000	129	1.08
C77351 - 3	2023501	12,000	107	0.89
C77351 - 4	2023501	9,500	122	1.28
C77353 - 1	2023701	6,100	83	1.36
C77353 - 2	2023701	5,900	80	1.35
Average		8,780	108	1.3
Low Value		5,500	80	0.89
High Value		12,000	122	1.84

Antimony (Sb)				
Sample I.D.	Station I.D.	Soil Concentration (μg/g)	Leach Concentration (μg/g)	% Leach
C77340 - 1	2022013	2.45	0.0040	0.16
C77340 - 2	2022013	1.82	0.0035	0.19
C77349 - 1	2023301	2.10	0.0033	0.16
C77349 - 2	2023301	2.33	0.0033	0.14
C77351 - 1	2023501	2.83	0.0036	0.13
C77351 - 2	2023501	2.52	0.0030	0.12
C77351 - 3	2023501	2.24	0.0033	0.15
C77351 - 4	2023501	2.01	0.0026	0.13
C77353 - 1	2023701	2.42	0.0025	0.10
C77353 - 2	2023701	2.05	0.0023	0.11
Average		2.28	0.0031	0.14
Low Value		1.82	0.0023	0.10
High Value		2.83	0.0040	0.19

Arsenic (As)				
Sample I.D.	Station I.D.	Soil Concentration (µg/g)	Leach Concentration (µg/g)	% Leach
C79545 - 1	2022013	52	0.70	1.35
C79545 - 2	2022013	39	0.56	1.44
C79546 - 1	2023301	45	0.58	1.29
C79546 - 2	2023301	50	0.69	1.38
C79547 - 1	2023501	63	0.40	0.63
C79547 - 2	2023501	45	0.39	0.87
C79547 - 3	2023501	43	0.43	1.0
C79547 - 4	2023501	42	0.53	1.26
C79548 - 1	2023701	62	0.54	0.87
C79548 - 2	2023701	38	0.51	1.34
Average		48	0.53	1.10
Low Value		38	0.39	0.63
High Value		63	0.70	1.44

Barium (Ba)				
Sample I.D.	Station I.D.	Soil Concentration (µg/g)	Leach Concentration (µg/g)	% Leach
C77340 - 1	2022013	130	4.5	3.5
C77340 - 2	2022013	140	4.6	3.3
C77349 - 1	2023301	160	5.4	3.4
C77349 - 2	2023301	150	4.8	3.2
C77351 - 1	2023501	210	5.5	2.6
C77351 - 2	2023501	200	5.7	2.9
C77351 - 3	2023501	200	4.6	2.3
C77351 - 4	2023501	190	5.2	2.8
C77353 - 1	2023701	120	3.7	3.1
C77353 - 2	2023701	94	4.5	4.8
Average		159	4.8	3.2
Low Value		94	3.7	2.3
High Value		200	5.5	4.8

Beryllium (Be)				
Sample I.D.	Station I.D.	Soil Concentration ($\mu g/g$)	Leach Concentration ($\mu g/g$)	% Leach
C77340 - 1	2022013	0.6<T	0.02<T	nc
C77340 - 2	2022013	0.5<W	0.02<T	nc
C77349 - 1	2023301	0.5<W	0.02<T	nc
C77349 - 2	2023301	0.5<W	0.02<T	nc
C77351 - 1	2023501	0.5<W	0.03<T	nc
C77351 - 2	2023501	0.5<W	0.03<T	nc
C77351 - 3	2023501	0.5<W	0.02<T	nc
C77351 - 4	2023501	0.5<W	0.03<T	nc
C77353 - 1	2023701	0.5<W	0.03<T	nc
C77353 - 2	2023701	0.5<W	0.02<T	nc
Average		0.5<W	0.024<T	nc
Low Value		0.5<W	0.02<T	nc
High Value		0.5<W	0.03<T	nc

Cadmium (Cd)				
Sample I.D.	Station I.D.	Soil Concentration ($\mu g/g$)	Leach Concentration ($\mu g/g$)	% Leach
C77340 - 1	2022013	0.2<W	0.04	nc
C77340 - 2	2022013	0.3<T	0.04	nc
C77349 - 1	2023301	0.2<W	0.08	nc
C77349 - 2	2023301	0.2<W	0.09	nc
C77351 - 1	2023501	0.2<W	0.06	nc
C77351 - 2	2023501	0.2<W	0.05	nc
C77351 - 3	2023501	0.2<W	0.05	nc
C77351 - 4	2023501	0.2<W	0.06	nc
C77353 - 1	2023701	0.2<W	0.04	nc
C77353 - 2	2023701	0.2<W	0.05	nc
Average		0.2<W	0.06	nc
Low Value		0.2<W	0.04	nc
High Value		0.3<T	0.09	nc

Calcium (Ca)				
Sample I.D.	Station I.D.	Soil Concentration ($\mu g/g$)	Leach Concentration ($\mu g/g$)	% Leach
C77340 - 1	2022013	9,900	491	4.96
C77340 - 2	2022013	11,000	541	4.92
C77349 - 1	2023301	22,000	1,010	4.59
C77349 - 2	2023301	23,000	1,040	4.52
C77351 - 1	2023501	30,000	1,360	4.53
C77351 - 2	2023501	29,000	1,390	4.79
C77351 - 3	2023501	33,000	1,470	4.45
C77351 - 4	2023501	29,000	1,280	4.41
C77353 - 1	2023701	14,000	645	4.61
C77353 - 2	2023701	16,000	689	4.31
Average		21,700	992	4.61
Low Value		9,900	491	4.31
High Value		33,000	1,360	4.96

Chromium (Cr)				
Sample I.D.	Station I.D.	Soil Concentration ($\mu g/g$)	Leach Concentration ($\mu g/g$)	% Leach
C77340 - 1	2022013	49	0.3	0.61
C77340 - 2	2022013	44	0.32	0.73
C77349 - 1	2023301	42	0.23	0.55
C77349 - 2	2023301	29	0.15	0.52
C77351 - 1	2023501	57	0.24	0.42
C77351 - 2	2023501	45	0.19	0.42
C77351 - 3	2023501	36	0.16	0.44
C77351 - 4	2023501	27	0.13	0.48
C77353 - 1	2023701	46	0.19	0.41
C77353 - 2	2023701	32	0.18	0.56
Average		41	0.21	0.51
Low Value		27	0.13	0.41
High Value		49	0.32	0.73

Cobalt (Co)				
Sample I.D.	Station I.D.	Soil Concentration (μg/g)	Leach Concentration (μg/g)	% Leach
C77340 - 1	2022013	200	.96	0.98
C77340 - 2	2022013	180	1.66	0.92
C77349 - 1	2023301	130	1.17	0.90
C77349 - 2	2023301	140	1.23	0.88
C77351 - 1	2023501	210	2.35	1.12
C77351 - 2	2023501	160	1.71	1.07
C77351 - 3	2023501	220	1.69	0.77
C77351 - 4	2023501	150	.85	1.23
C77353 - 1	2023701	230	1.44	0.63
C77353 - 2	2023701	120	1.29	1.08
Average		174	1.64	0.96
Low Value		120	0.85	0.63
High Value		220	2.35	1.23

Copper (Cu)				
Sample I.D.	Station I.D.	Soil Concentration (μg/g)	Leach Concentration (μg/g)	% Leach
C77340 - 1	2022013	990	17.2	1.74
C77340 - 2	2022013	770	17.1	2.22
C77349 - 1	2023301	1000	19.1	1.91
C77349 - 2	2023301	780	14.2	1.82
C77351 - 1	2023501	1000	15.9	1.59
C77351 - 2	2023501	840	14.7	1.75
C77351 - 3	2023501	1000	20.5	2.05
C77351 - 4	2023501	980	20.7	2.11
C77353 - 1	2023701	970	16.1	1.66
C77353 - 2	2023701	640	14.0	2.19
Average		897	17	1.90
Low Value		640	14.0	1.59
High Value		1000	20.7	2.22

IRON (Fe)				
Sample I.D.	Station I.D.	Soil Concentration ($\mu g/g$)	Leach Concentration ($\mu g/g$)	% Leach
C77340 - 1	2022013	130,000	254	0.20
C77340 - 2	2022013	90,000	252	0.28
C77349 - 1	2023301	77,000	261	0.34
C77349 - 2	2023301	48,000	162	0.34
C77351 - 1	2023501	90,000	251	0.28
C77351 - 2	2023501	93,000	195	0.21
C77351 - 3	2023501	60,000	142	0.24
C77351 - 4	2023501	62,000	131	0.21
C77353 - 1	2023701	130,000	245	0.19
C77353 - 2	2023701	66,000	201	0.30
Average		84,600	209	0.26
Low Value		48,000	142	0.19
High Value		130,000	261	0.34

Lead (Pb)				
Sample I.D.	Station I.D.	Soil Concentration ($\mu g/g$)	Leach Concentration ($\mu g/g$)	% Leach
C77340 - 1	2022013	400	15.6	3.9
C77340 - 2	2022013	480	21.1	4.4
C77349 - 1	2023301	350	12.8	3.7
C77349 - 2	2023301	310	11.1	3.6
C77351 - 1	2023501	400	13.3	3.3
C77351 - 2	2023501	370	14.4	3.9
C77351 - 3	2023501	300	9.17	3.1
C77351 - 4	2023501	350	11.4	3.3
C77353 - 1	2023701	360	15.4	4.3
C77353 - 2	2023701	290	13.1	4.5
Average		361	13.74	3.8
Low Value		290	9.17	3.1
High Value		480	21.1	4.5

Magnesium (Mg)				
Sample I.D.	Station I.D.	Soil Concentration ($\mu g/g$)	Leach Concentration ($\mu g/g$)	% Leach
C77340 - 1	2022013	3,200	102	3.19
C77340 - 2	2022013	3,300	111	3.36
C77349 - 1	2023301	6,600	238	3.61
C77349 - 2	2023301	6,500	228	3.51
C77351 - 1	2023501	10,000	374	3.74
C77351 - 2	2023501	10,000	382	3.82
C77351 - 3	2023501	10,000	371	3.71
C77351 - 4	2023501	8,400	307	3.65
C77353 - 1	2023701	5,500	194	3.53
C77353 - 2	2023701	5,900	207	3.51
Average		6,940	251	3.56
Low Value		3,200	102	3.19
High Value		10,000	382	3.82

Manganese (Mn)				
Sample I.D.	Station I.D.	Soil Concentration ($\mu g/g$)	Leach Concentration ($\mu g/g$)	% Leach
C77340 - 1	2022013	1200	35.3	2.94
C77340 - 2	2022013	1100	35.9	3.26
C77349 - 1	2023301	980	33.4	3.41
C77349 - 2	2023301	720	25.6	3.56
C77351 - 1	2023501	1200	36.5	3.04
C77351 - 2	2023501	1000	32.6	3.26
C77351 - 3	2023501	960	30.8	3.21
C77351 - 4	2023501	1100	33.2	3.02
C77353 - 1	2023701	1100	33.0	3.00
C77353 - 2	2023701	800	29.0	3.62
Average		1016	32.5	3.23
Low Value		720	25.6	2.92
High Value		1200	35.9	3.62

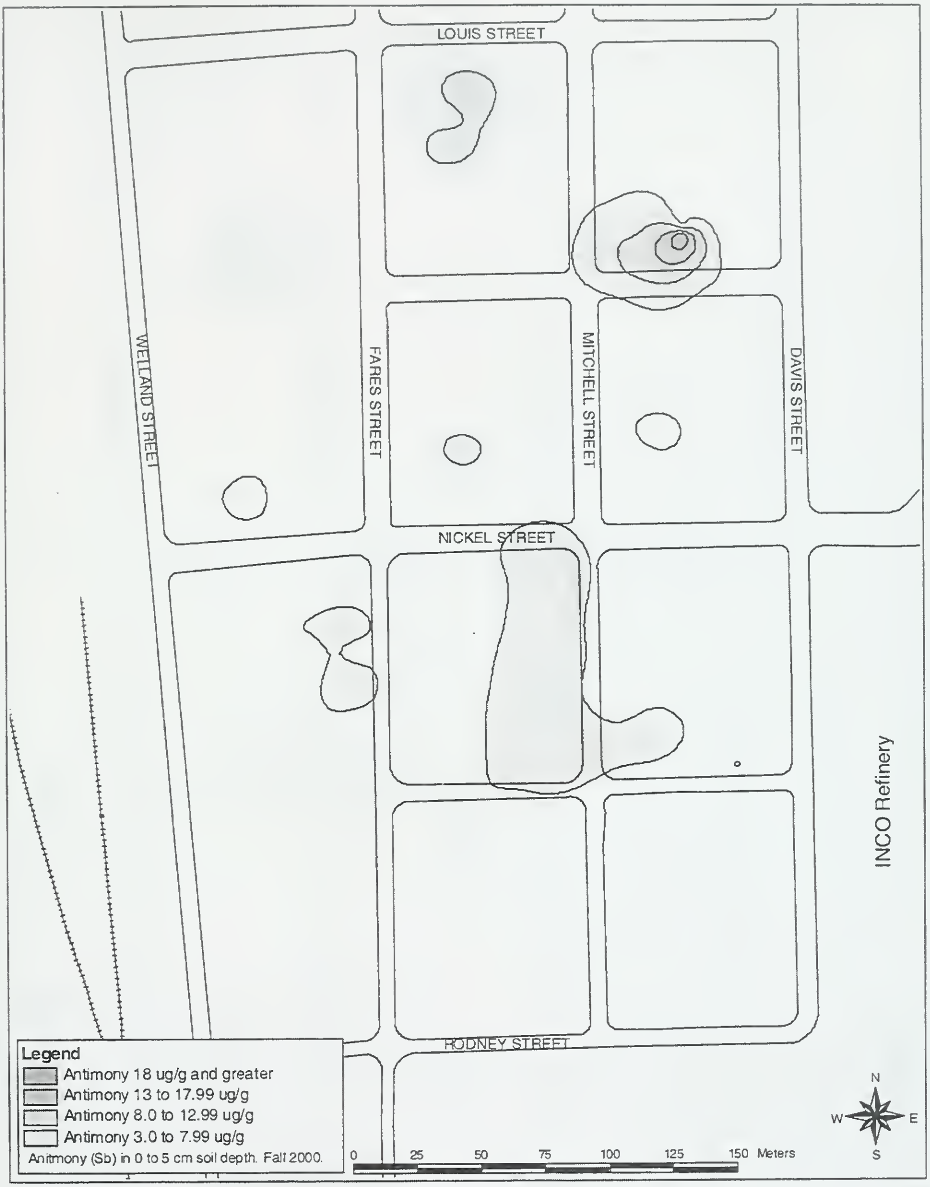
Nickel (Ni)				
Sample I.D.	Station I.D.	Soil Concentration (μg/g)	Leach Concentration (μg/g)	% Leach
C77340 - 1	2022013	16,000	104	0.65
C77340 - 2	2022013	9,200	107	1.16
C77349 - 1	2023301	14,000	127	0.91
C77349 - 2	2023301	11,000	93	0.85
C77351 - 1	2023501	14,000	115	0.82
C77351 - 2	2023501	13,000	97	0.75
C77351 - 3	2023501	12,000	89	0.74
C77351 - 4	2023501	11,000	88	0.8
C77353 - 1	2023701	17,000	100	0.59
C77353 - 2	2023701	8,000	86	0.98
Average		12,600	101	0.82
Low Value		8,000	86	0.59
High Value		17,000	107	1.16

Selenium (Se)				
Sample I.D.	Station I.D.	Soil Concentration (μg/g)	Leach Concentration (μg/g)	% Leach
C77340 - 1	2022013	7.0	0.001 <T	nc
C77340 - 2	2022013	7.0	0.001<T	nc
C77349 - 1	2023301	8.4	0.001<T	nc
C77349 - 2	2023301	8.3	0.001<T	nc
C77351 - 1	2023501	12.3	0.0008<T	nc
C77351 - 2	2023501	10.0	0.0006<T	nc
C77351 - 3	2023501	7.6	0.0005<W	nc
C77351 - 4	2023501	6.4	0.0005<W	nc
C77353 - 1	2023701	11.1	0.0009<T	nc
C77353 - 2	2023701	7.8	0.0009<T	nc
Average		8.6	-	nc
Low Value		6.4	0.0005<W	nc
High Value		12.3	0.001<T	nc

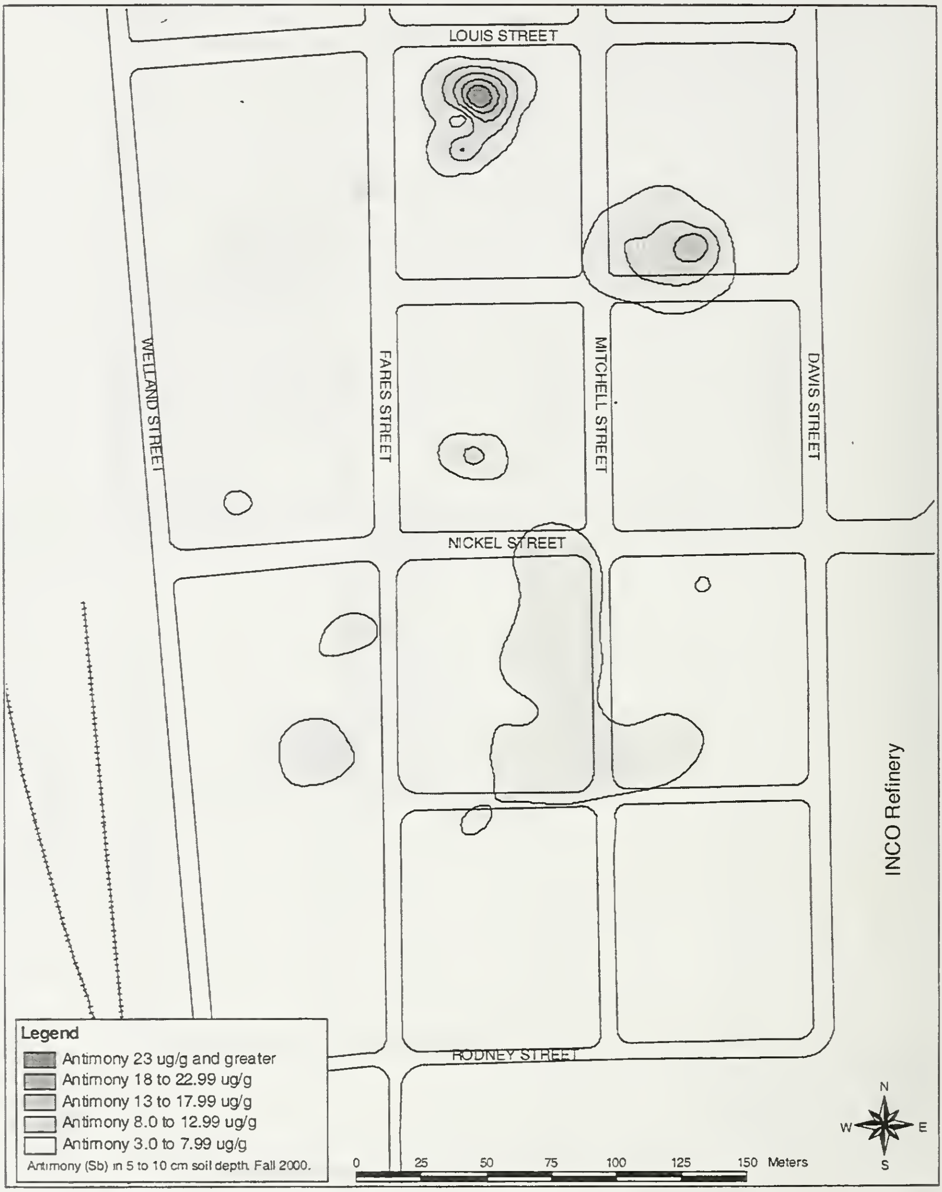
Strontium (Sr)				
Sample I.D.	Station I.D.	Soil Concentration (μg/g)	Leach Concentration (μg/g)	% Leach
C77340 - 1	2022013	37	1.52	4.11
C77340 - 2	2022013	41	1.59	3.88
C77349 - 1	2023301	68	2.92	4.29
C77349 - 2	2023301	81	3.23	3.99
C77351 - 1	2023501	95	3.54	3.73
C77351 - 2	2023501	100	4.18	4.18
C77351 - 3	2023501	100	4.46	4.46
C77351 - 4	2023501	110	4.24	3.85
C77353 - 1	2023701	37	1.44	3.89
C77353 - 2	2023701	37	1.46	3.95
Average		70.6	2.86	4.03
Low Value		37	1.44	3.73
High Value		110	4.46	4.46

Vanadium (V)				
Sample I.D.	Station I.D.	Soil Concentration (μg/g)	Leach Concentration (μg/g)	% Leach
C77340 - 1	2022013	34	0.40	1.18
C77340 - 2	2022013	29	0.41	1.41
C77349 - 1	2023301	34	0.44	1.29
C77349 - 2	2023301	31	0.40	1.29
C77351 - 1	2023501	39	0.35	0.90
C77351 - 2	2023501	41	0.44	1.07
C77351 - 3	2023501	36	0.28	0.78
C77351 - 4	2023501	32	0.26	0.81
C77353 - 1	2023701	30	0.30	1.00
C77353 - 2	2023701	24	0.31	1.29
Average		33	0.36	1.10
Low Value		24	0.28	0.78
High Value		41	0.44	1.41

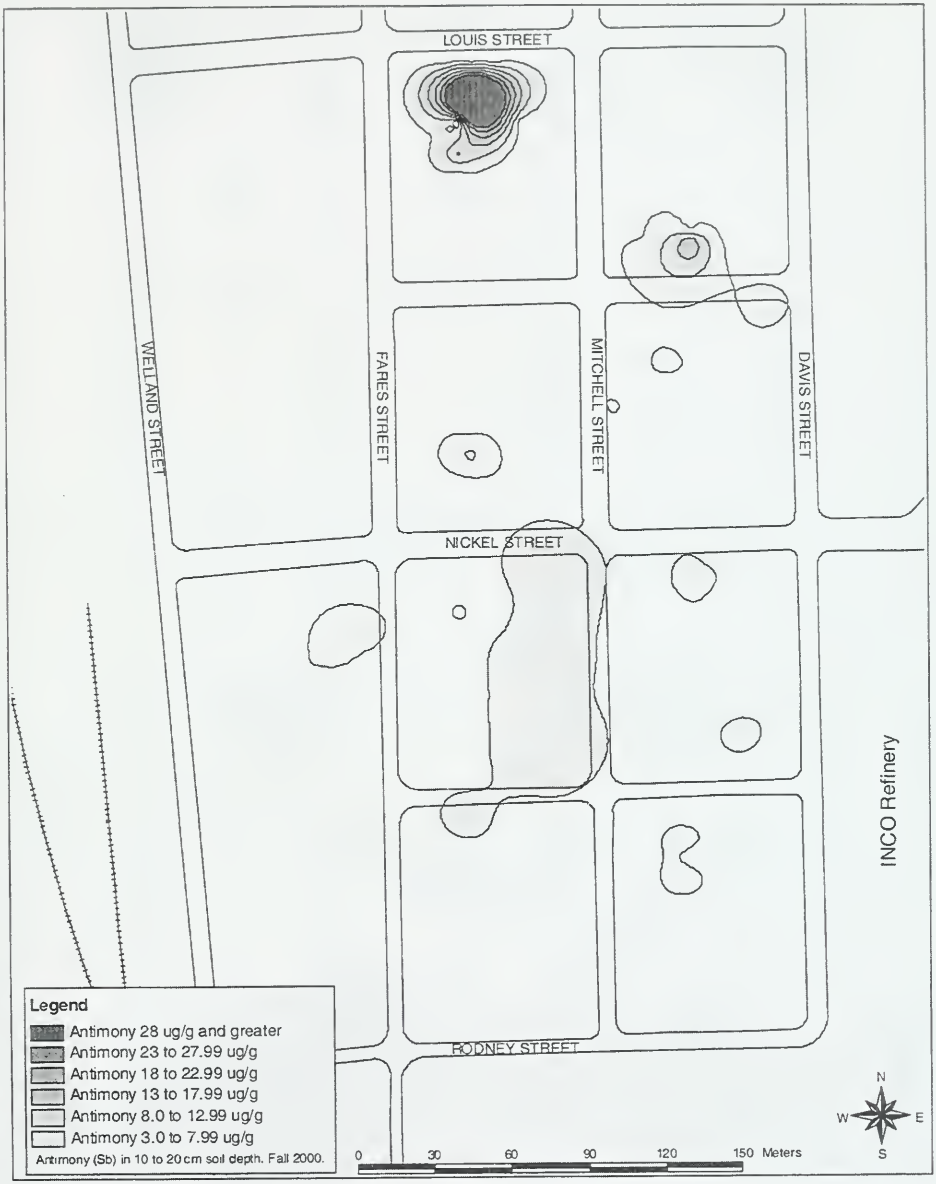
Zinc (Zn)				
Sample I.D.	Station I.D.	Soil Concentration ($\mu g/g$)	Leach Concentration ($\mu g/g$)	% Leach
C77340 - 1	2022013	1100	23.6	2.5
C77340 - 2	2022013	990	24.0	2.42
C77349 - 1	2023301	930	20.5	2.2
C77349 - 2	2023301	690	15.2	2.2
C77351 - 1	2023501	1100	24.3	2.21
C77351 - 2	2023501	1000	21.2	2.12
C77351 - 3	2023501	830	17.7	2.13
C77351 - 4	2023501	840	18.3	2.18
C77353 - 1	2023701	1000	20.4	2.04
C77353 - 2	2023701	700	17.1	2.44
Average		918	20.2	2.21
Low Value		690	15.2	2.04
High Value		1100	24.3	2.44



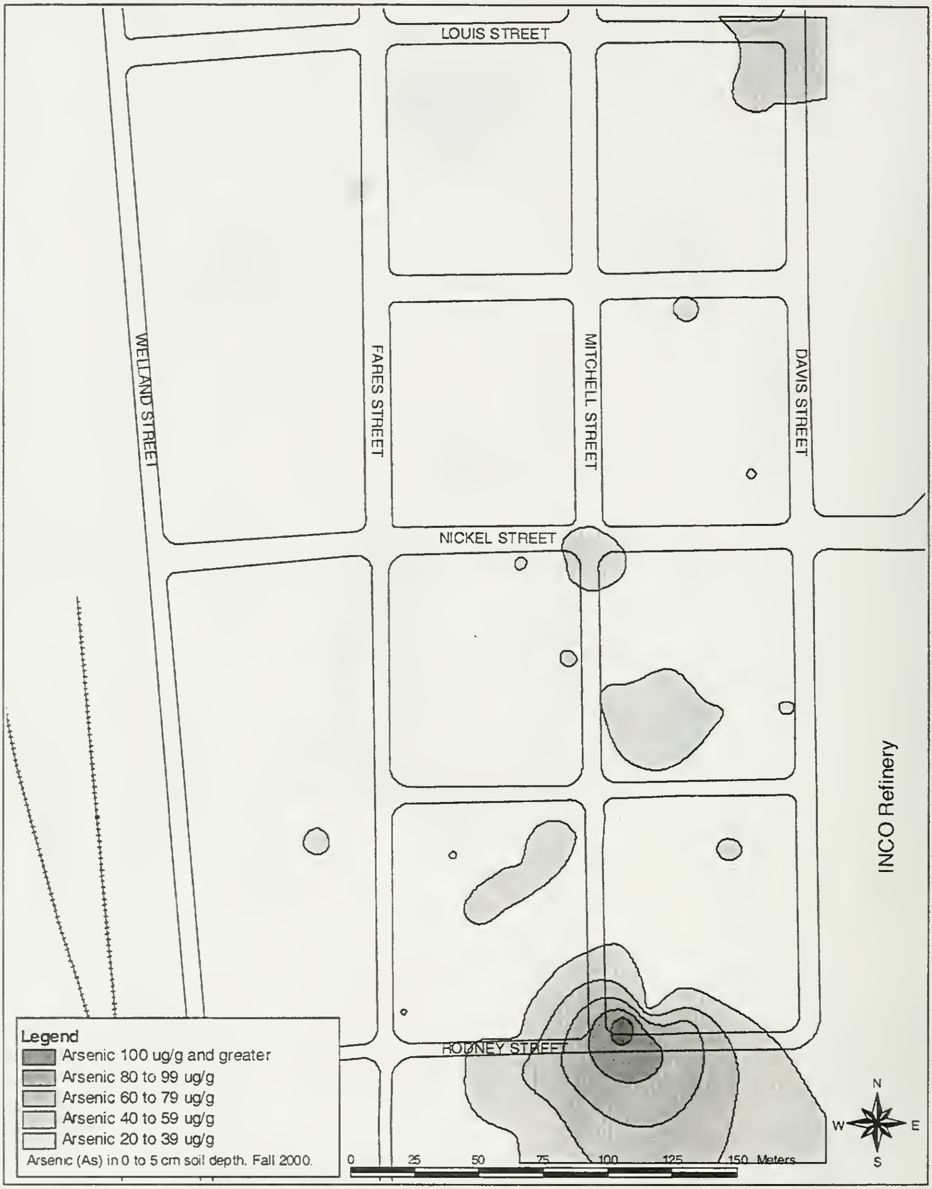
Map B1: Antimony in 0 to 5 cm soil depth.



Map B2: Antimony in 5 to 10 cm soil depth.



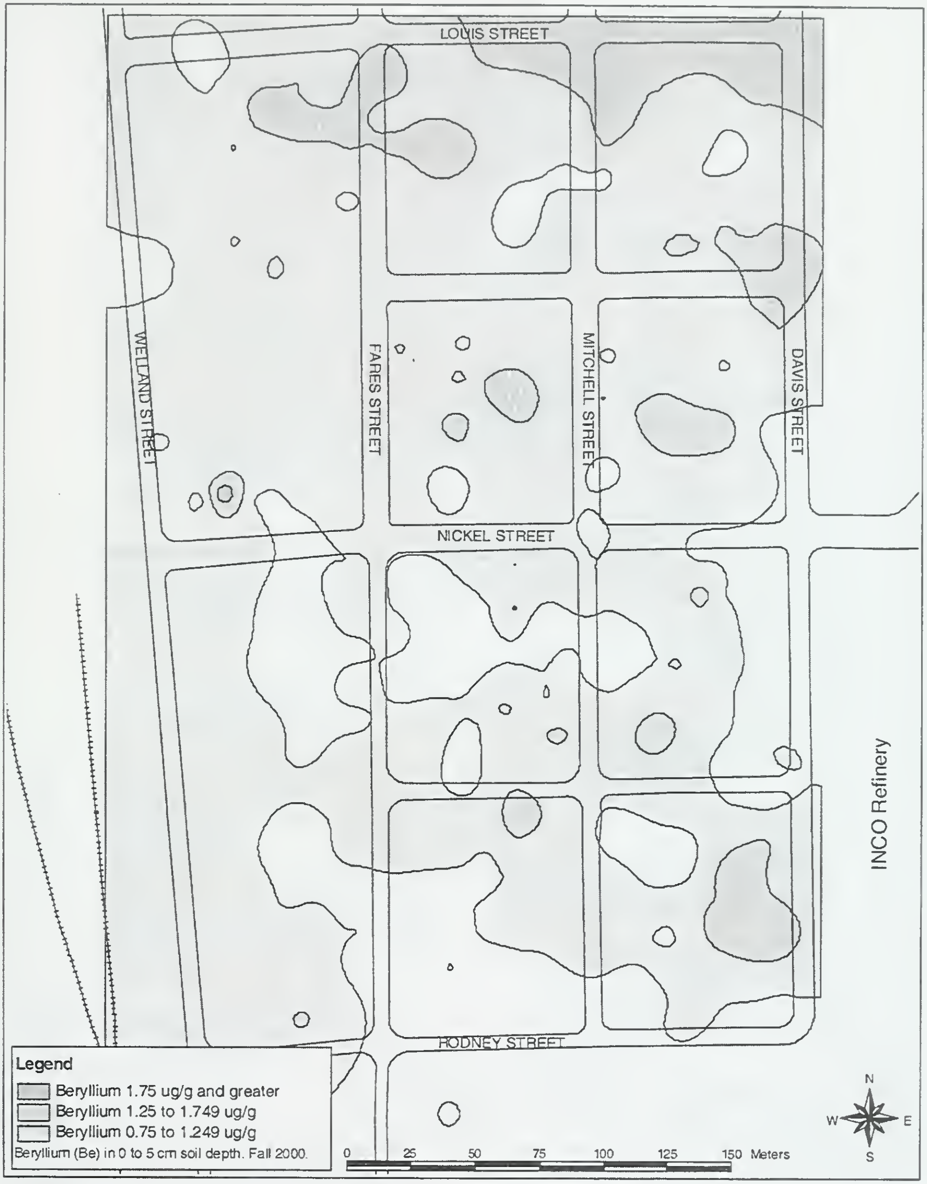
Map B3: Antimony in 10 to 20 cm soil depth.



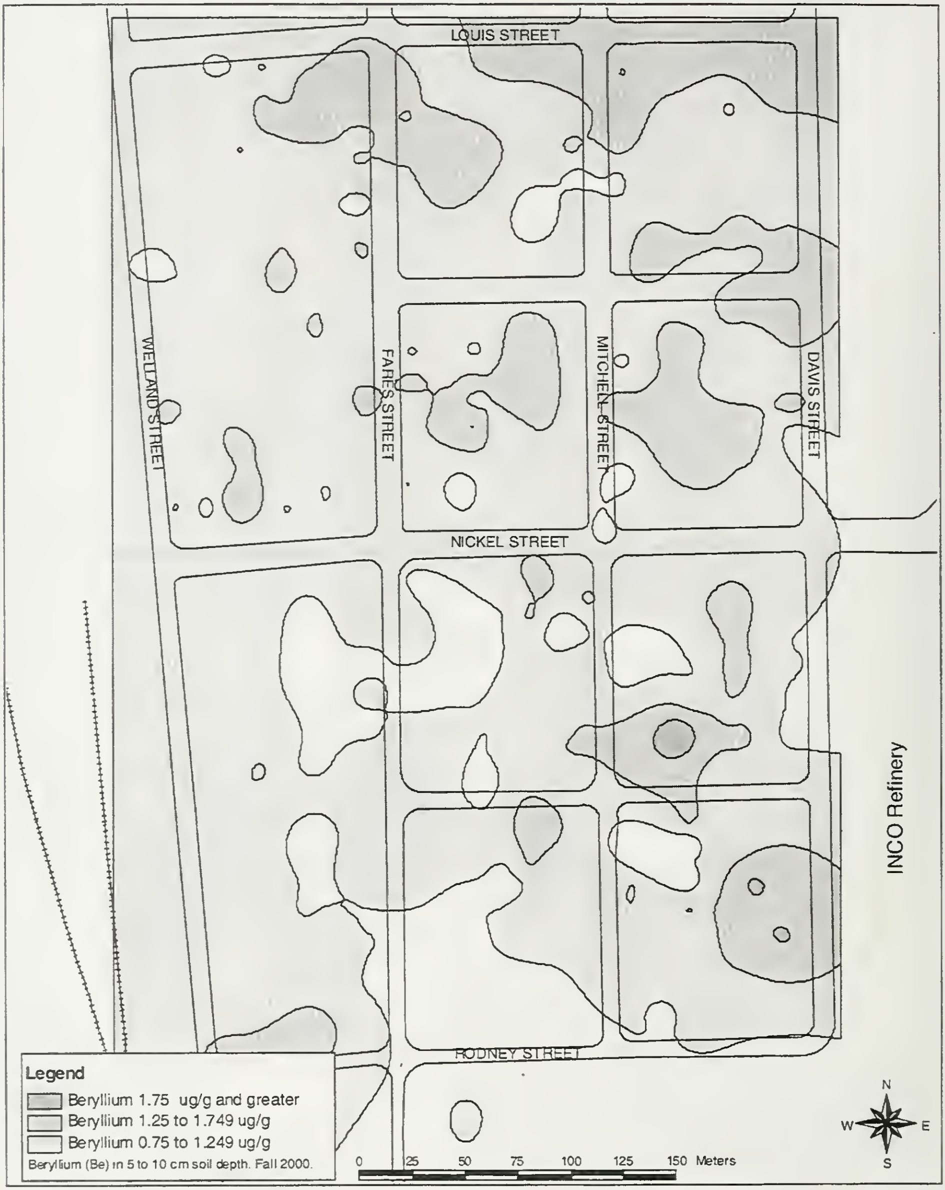
Map B4: Arsenic in 0 to 5 cm soil depth.

Map B5: Arsenic in 5 to 10 cm soil depth.

Map B6: Arsenic in 10 to 20 cm soil depth.

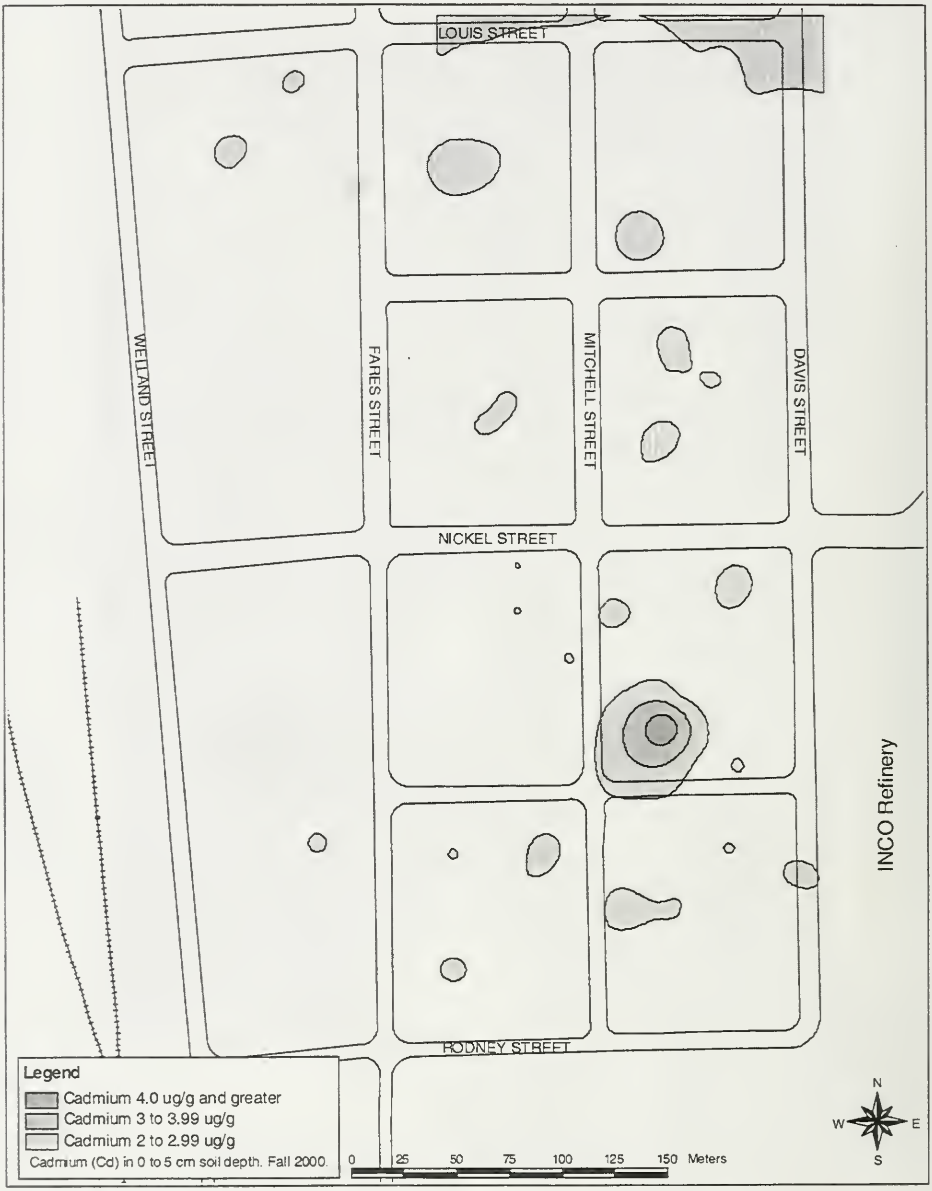


Map B7: Beryllium in 0 to 5 cm soil depth.

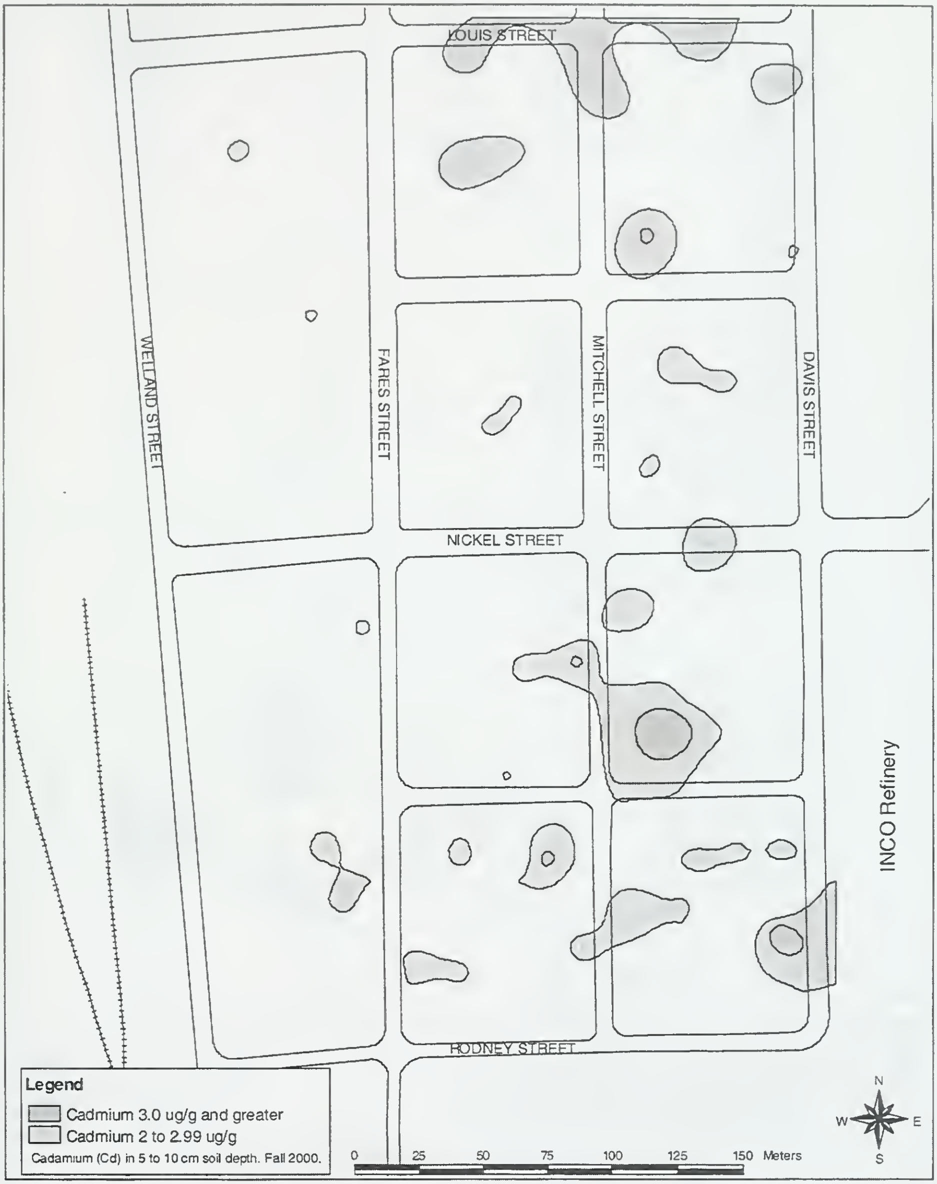


Map B8: Beryllium in 5 to 10 cm depth.

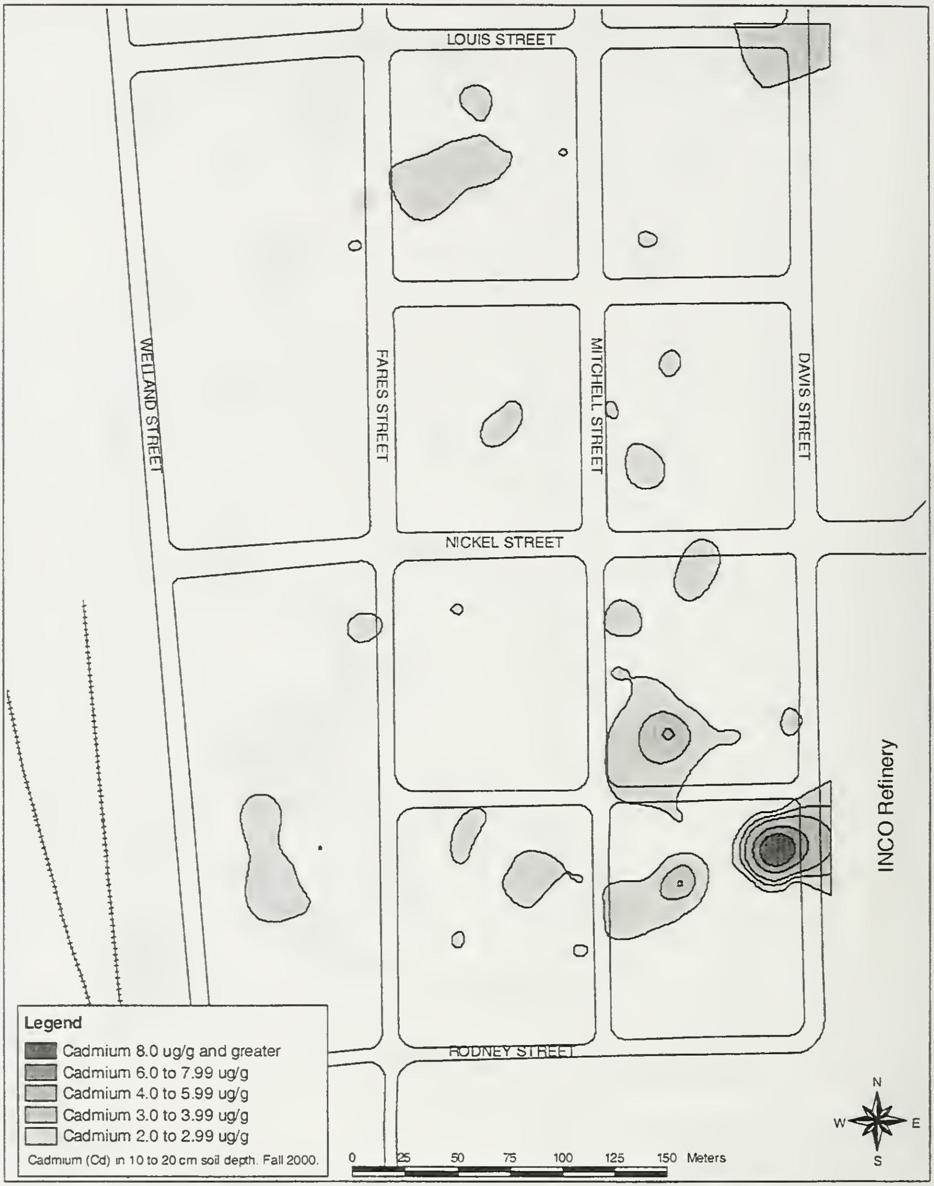
Map B9: Beryllium in 10 to 20 soil depth.



Map B10: Cadmium in 0 to 5 cm soil depth.



Map B11: Cadmium in 5 to 10 cm soil depth.

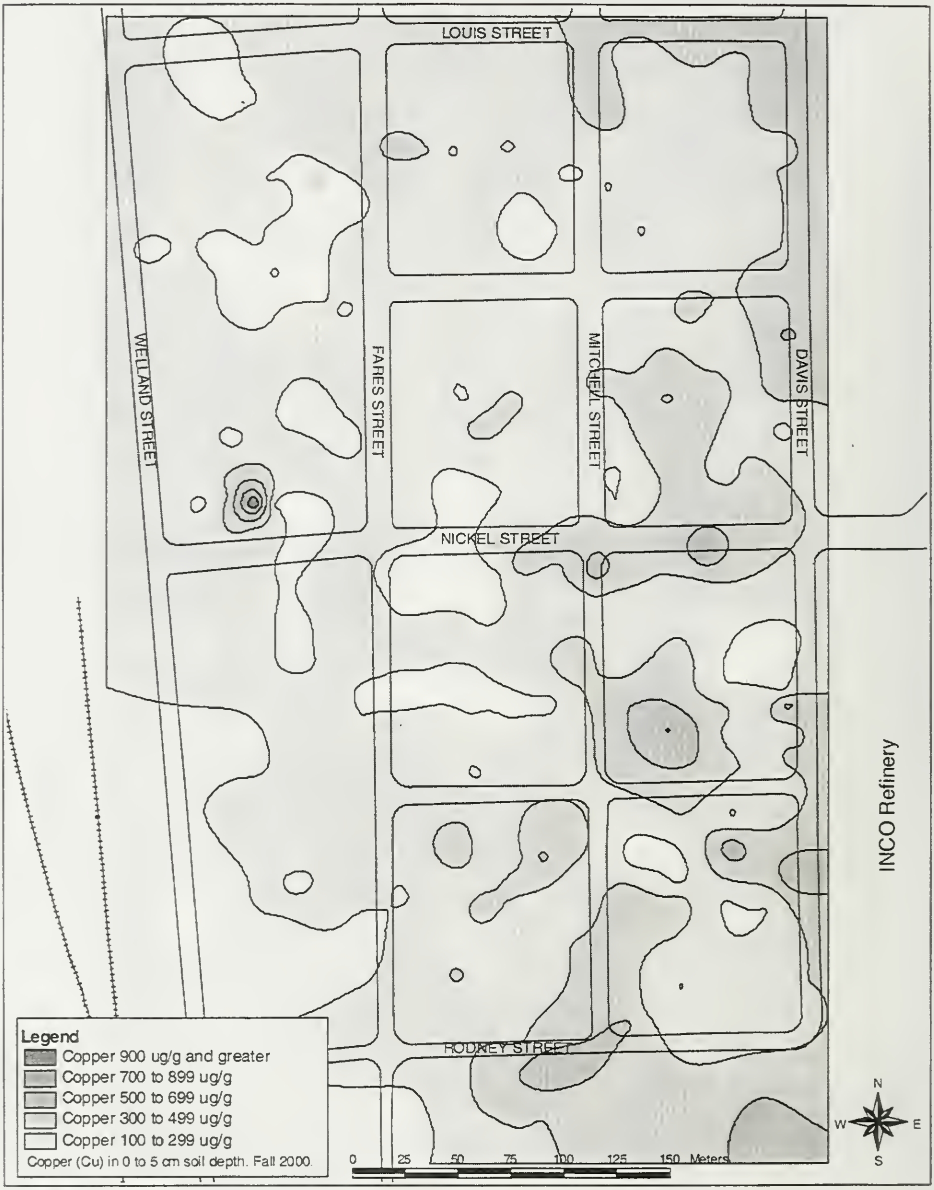


Map B12: Cadmium in 10 to 20 cm soil depth.

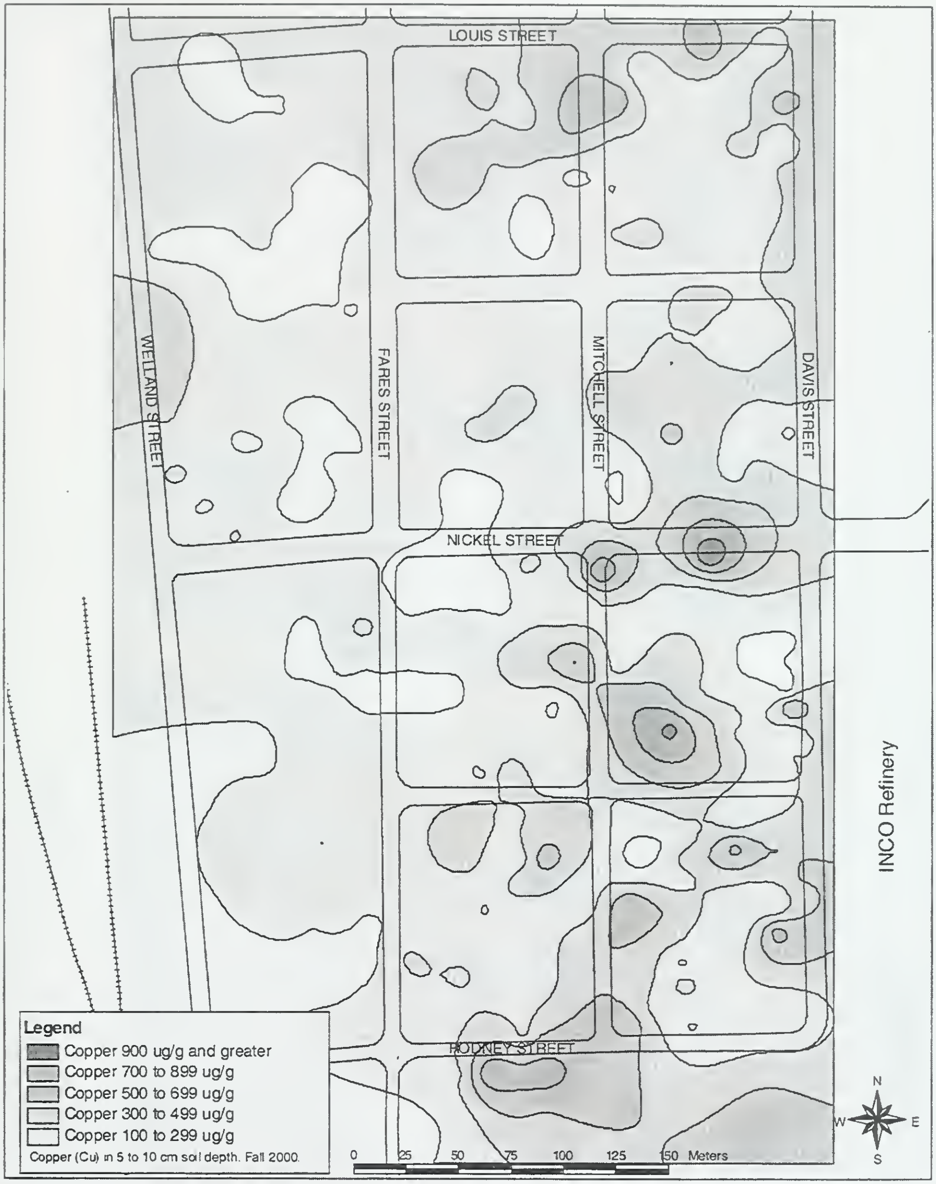
Map B13: Cobalt in 0 to 5 cm soil depth.

Map B14: Cobalt in 5 to 10 cm soil depth.

Map B15: Cobalt in 10 to 20 cm soil depth.

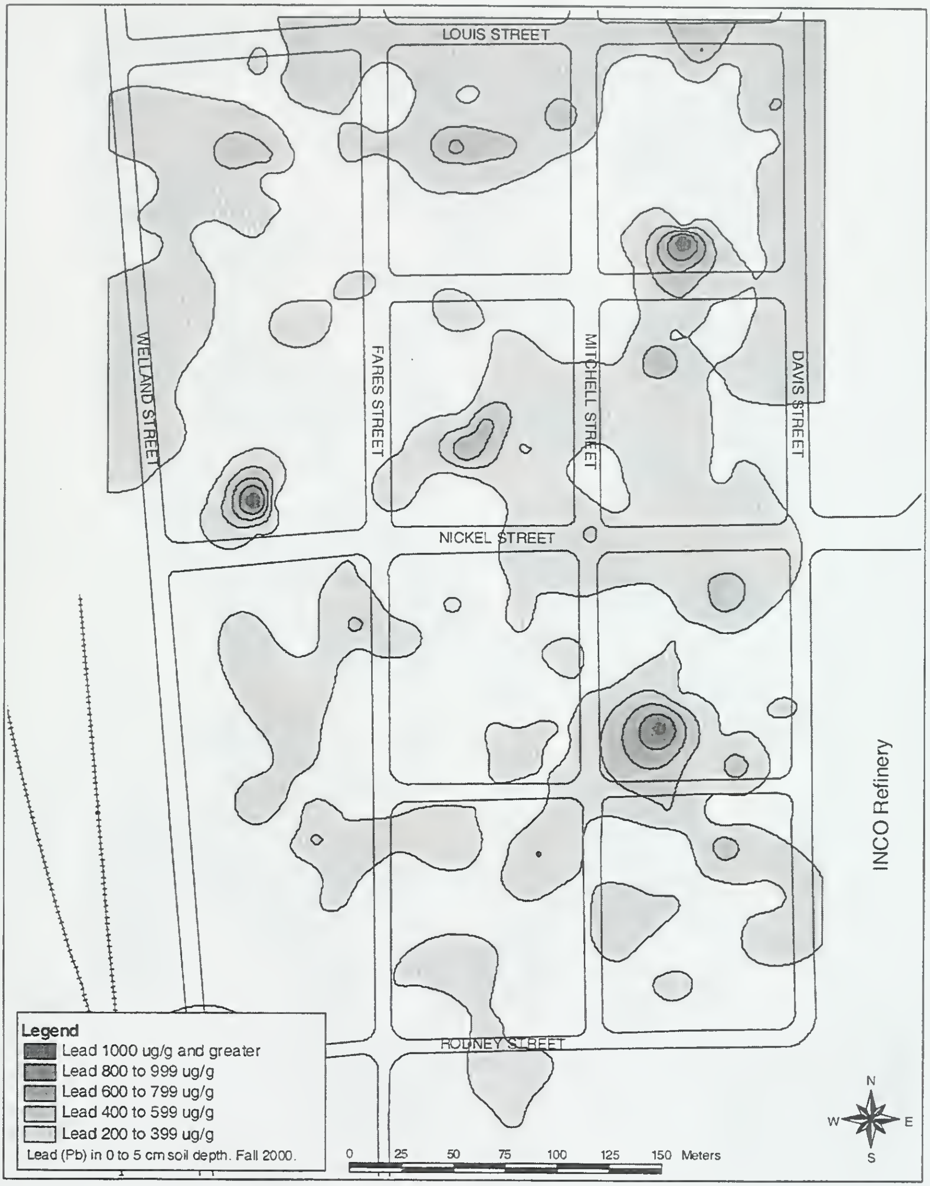


Map B16: Copper in 0 to 5 cm soil depth.



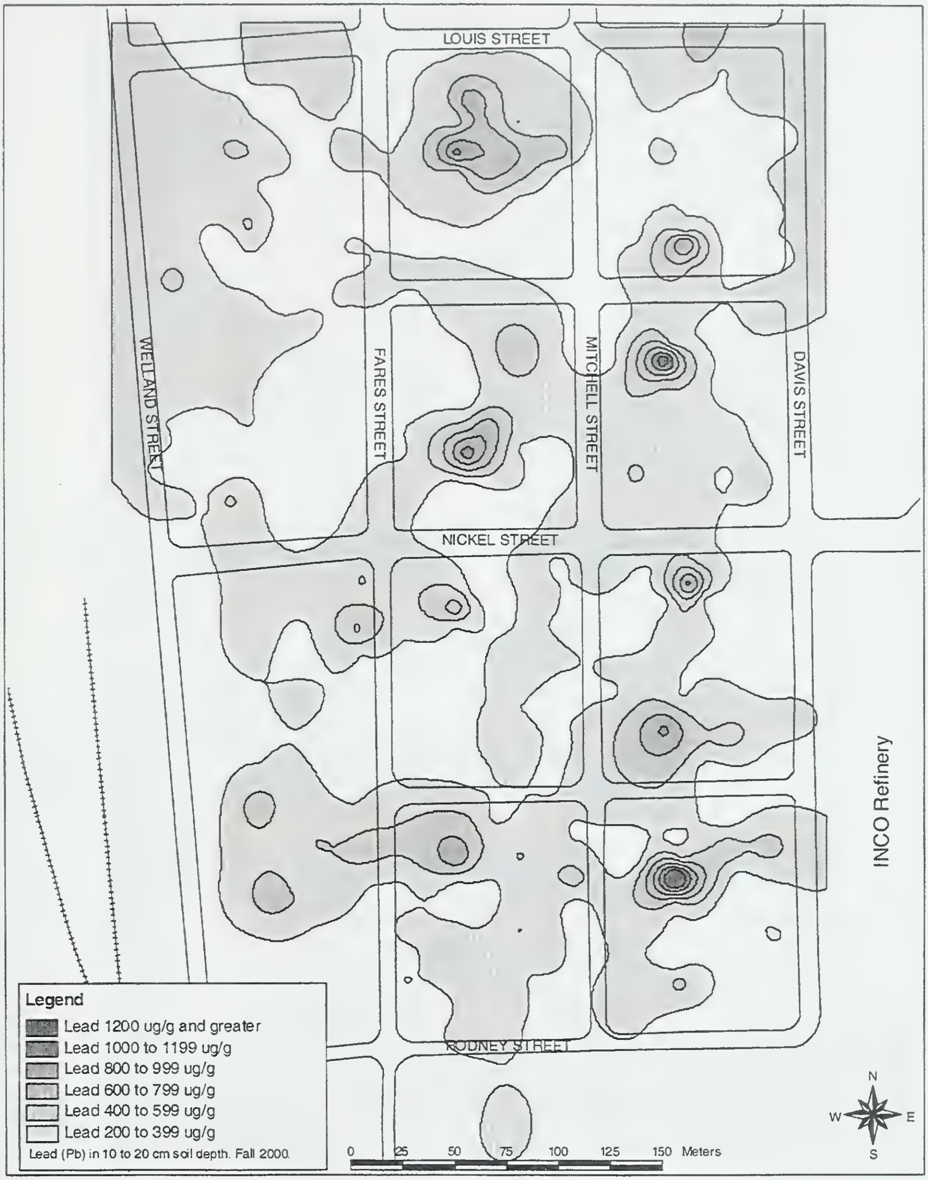
Map B17: Copper in 5 to 10 cm soil depth.

Map B18: Copper in 10 to 20 cm soil depth.

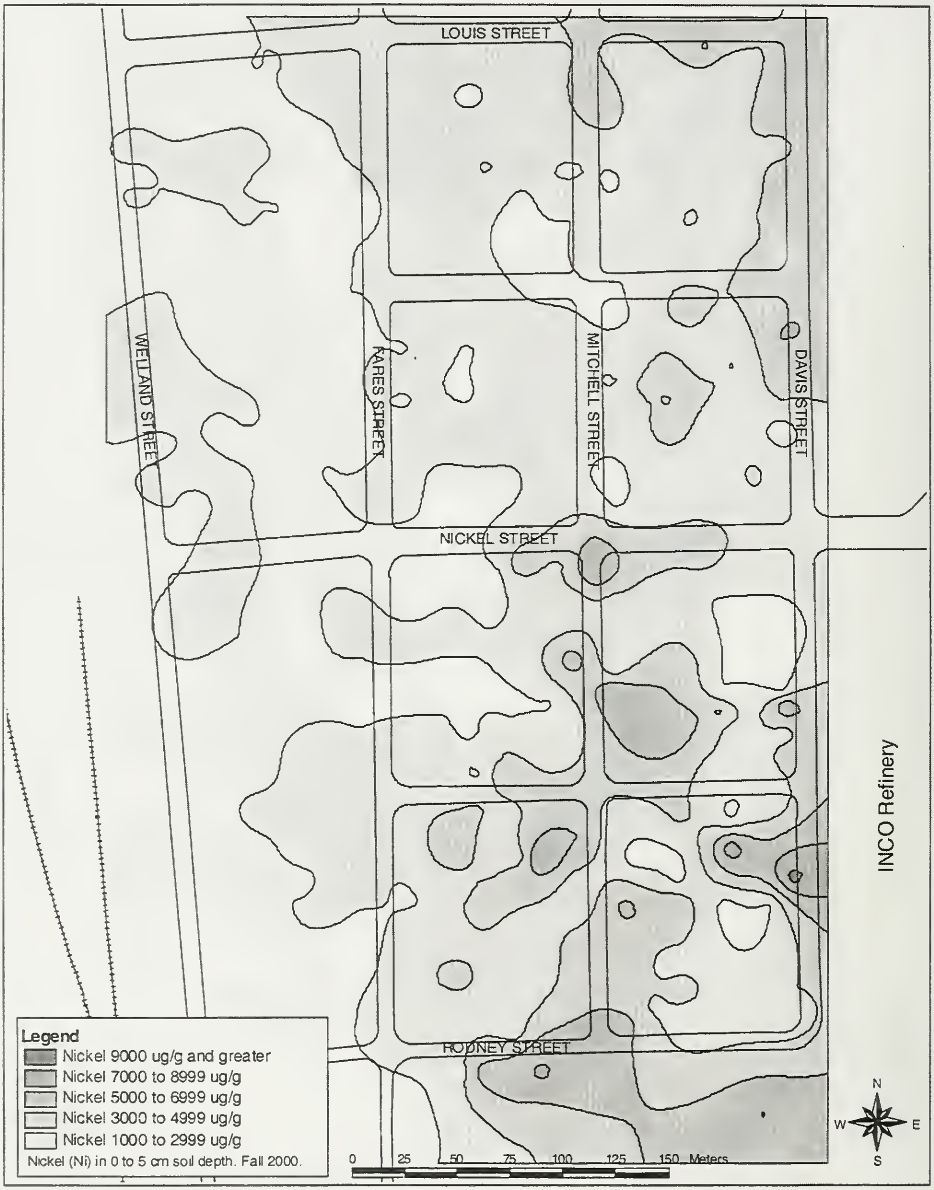


Map B19: Lead in 0 to 5 cm depth soil.

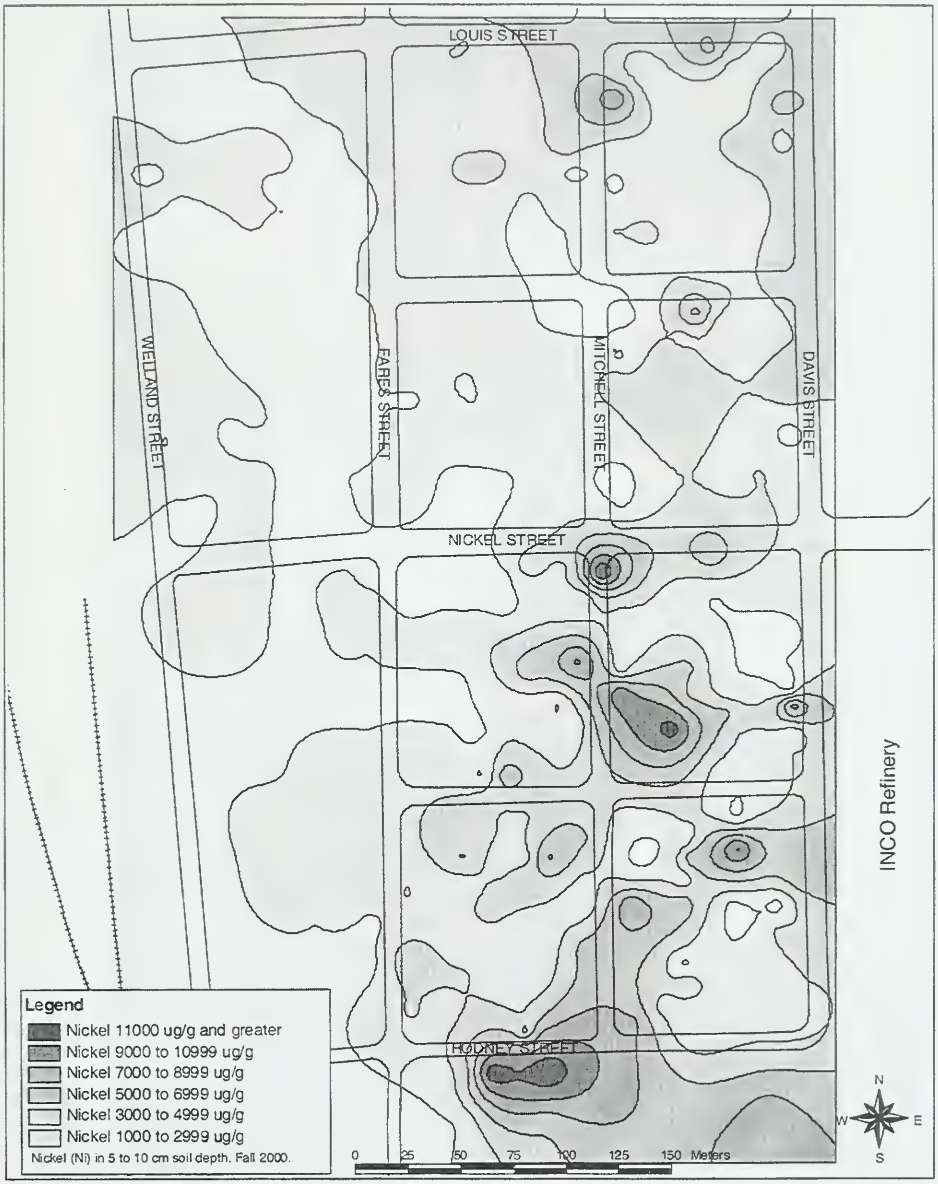
Map B20: Lead in 5 to 10 cm soil depth.



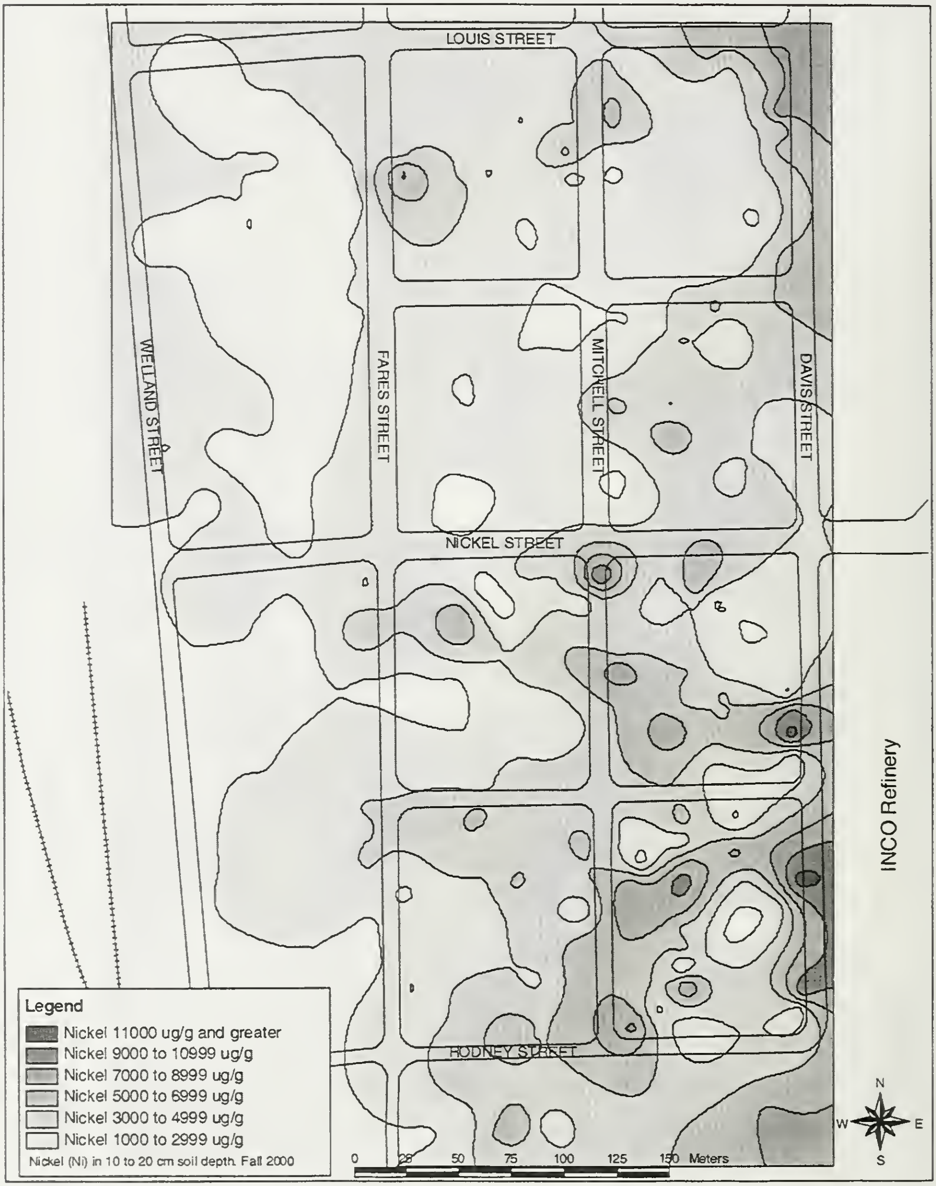
Map B21: Lead in 10 to 20 cm soil depth.



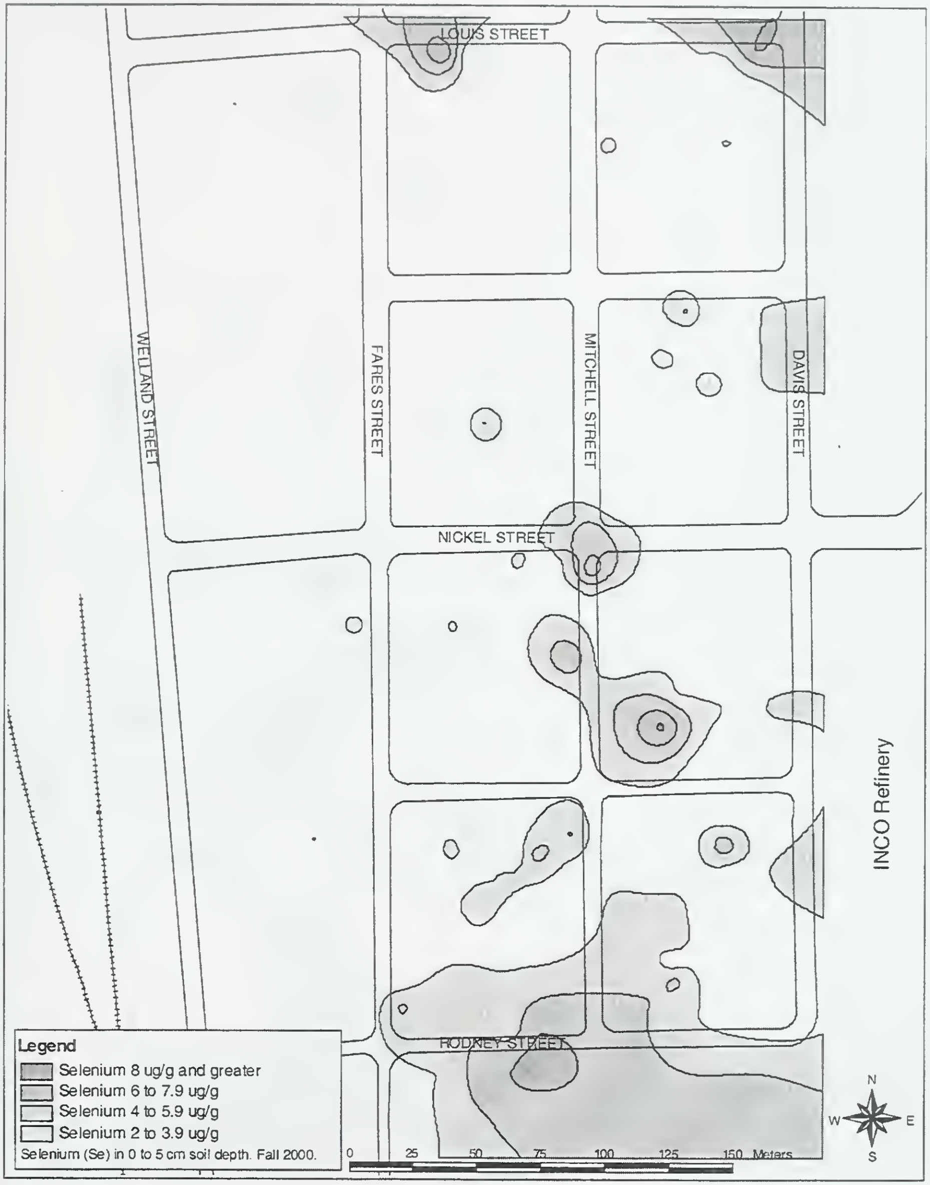
Map B22: Nickel in 0 to 5 cm soil depth.



Map B23: Nickel in 5 to 10 cm soil depth.



Map B24: Nickel in 10 to 20 cm soil depth.



Map B25: Selenium in 0 to 5 cm soil depth.

Map B26: Selenium in 5 to 10 cm soil depth.

Map B27: Selenium in 10 to 20 cm soil depth.

Methodology for Producing Surfer/ArcView Soil Contamination Maps

Software Utilized

Two software packages were used to generate the maps. The data analysis and creation of the concentration contours was done using Surfer Version 7.00 for Windows by Golden Software Inc. The output from Surfer was imported into ArcView GIS Version 3.1 by Environmental Systems Research Institute, Inc., and combined with base maps, roads and properties, to produce the final maps. The base map data was obtained from the City of Port Colborne, Public Works Department.

Data Used

For the contour maps produced in this report, all sampling stations collected south of Louis St in the fall of 2000 as part of the large survey or as individual complaint investigations, were used to generate the contours.

Mapping Process

The process involved in creating the maps was to analyze the data and create the desired contours using the Surfer program. The individual contours were exported from Surfer as ESRI Shape files. The polygon portion of the Shape files were imported into ArcView GIS and modified to remove polygon holes created by the export process. The resulting polygons were combined with the street base maps, and the station locations were imported from the Phytotoxicology Information Management System (PIMS). Layouts were then created to include a legend, labels, scale and compass and printed for the report.

Surfer

For all data sets, a Krigging gridding method was used and the search option was set to use all data. For all contours, smoothing was set at high. All co-ordinates were in Universal Trans Mercator (UTM) Easting and Northing. Where duplicate or triplicate samples existed for a sampling location the program was set to use the average of the results.

Surfer Settings

Grid Line Geometry				
	Minimum	**Maximum**	**Spacing**	**# of Lines**
X Axis (Easting)	643185 m	643527 m	3 m	115
Y Axis (Northing)	4748834 m	4749383 m	3 m	184
Duplicates - averaged Matrix Smoothing - none				

Arc View

Station Map

A base map was created by importing the Autocad DXF files provided by the City of Port Colborne, Works Department and converting to Arcview Shape files. Only the road, rail lines, property boundaries and building foot prints layers were turned on. To this was added all of the stations sampled in the fall of 2000 by importing the station co-ordinates and related information from the PIMS database.

Contour Maps

The street layer of the station map was used as the underlying map for all contour maps. Property boundaries, building foot prints and street numbers were not included. The polygon for each contour interval were imported into Arcview as individual shape files from Surfer, any polygon holes removed and combined with the other contour intervals. Grey scales were used to differentiate contours for printing purposes.

Final Maps

A separate ArcView layout was produced for each of the maps and consisted of a base map, contour polygons, scale, compass and legend. Sampling stations were included on the contour polygons maps. These layouts were imported into the report.

Appendix C: Analysis of Chemical Relationships

Table C1: Results of Pearson Correlation Test on soil data from all depths.

Parameter	Al	Sb	As	Ba	Be	Cd	Ca	Cr	Co	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Se	Sr	V	Zn
Aluminum (Al)	1																			
Antimony (Sb)	0	1																		
Arsenic (As)	-0.2	0.16	1.00																	
Barium (Ba)	0.35	0.22	0.20	1.00																
Beryllium (Be)	0.79	0.1	0	0.60	1.00															
Cadmium (Cd)	0.16	0.14	0.12	0.44	0.28	1.00														
Calcium (Ca)	0.11	0.1	0	0.34	0.28	0.13	1.00													
Chromium (Cr)	0.45	0.11	0.34	0.47	0.52	0.26	0.14	1.00												
Cobalt (Co)	0	0.1	0.56	0.31	0.11	0.27	0.1	0.36	1											
Copper (Cu)	0	0.16	0.56	0.46	0.16	0.33	0.14	0.37	0.84	1.00										
Iron (Fe)	0	0.15	0.59	0.34	0.17	0.2	0.14	0.41	0.75	0.71	1.00									
Lead (Pb)	0	0.38	0.28	0.74	0.29	0.41	0.27	0.30	0.36	0.50	0.37	1								
Magnesium (Mg)	0.44	0	-0.2	0.21	0.4	0.1	0.69	0.23	0	0	0	0.1	1.00							
Manganese (Mn)	0.1	0.1	0.25	0.23	0.21	0.11	0.25	0.23	0.34	0.31	0.49	0.18	0.15	1.00						
Molybdenum (Mo)	0.25	0	-0.2	0.2	0.32	0.19	0.17	0.16	0	0	0	0.12	0.25	0.14	1.00					
Nickel (Ni)	-0.1	0.1	0.6	0.33	0.1	0.29	0.08	0.33	0.93	0.87	0.82	0.41	0	0.35	-0.1	1.00				
Selenium (Se	-0.4	0.11	0.56	0.1	-0.2	0.1	0	0.13	0.73	0.66	0.68	0.26	-0.2	0.27	-0.3	0.77	1.00			
Strontium (Sr	0.1	0.14	0.1	0.44	0.33	0.18	0.67	0.2	0.1	0.19	0.16	0.36	0.30	0.12	0.1	0.11	0.1	1.00		
Vanadium (V)	0.89	0	0	0.37	0.75	0.13	0.1	0.49	0.1	0	0.13	0	0.44	0.11	0.15	0	-0.3	0.1	1.00	
Zinc (Zn)	-0.1	0.23	0.5	0.67	0.23	0.42	0.21	0.42	0.66	0.77	0.65	0.75	0	0.3	0	0.71	0.57	0.34	0	1

All values > 0.08 are significantly correlated to the 95% level

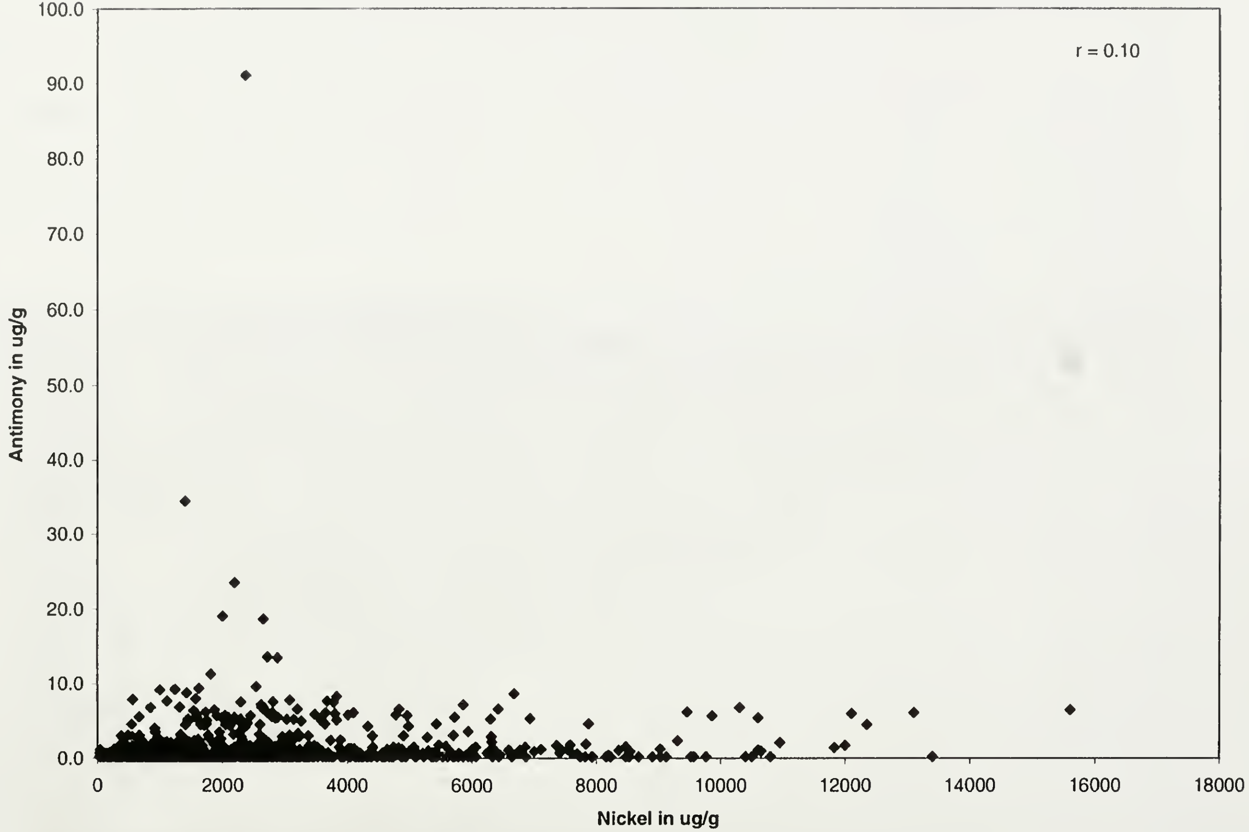


Figure C1: Relationship between antimony and nickel in soil for all depths.

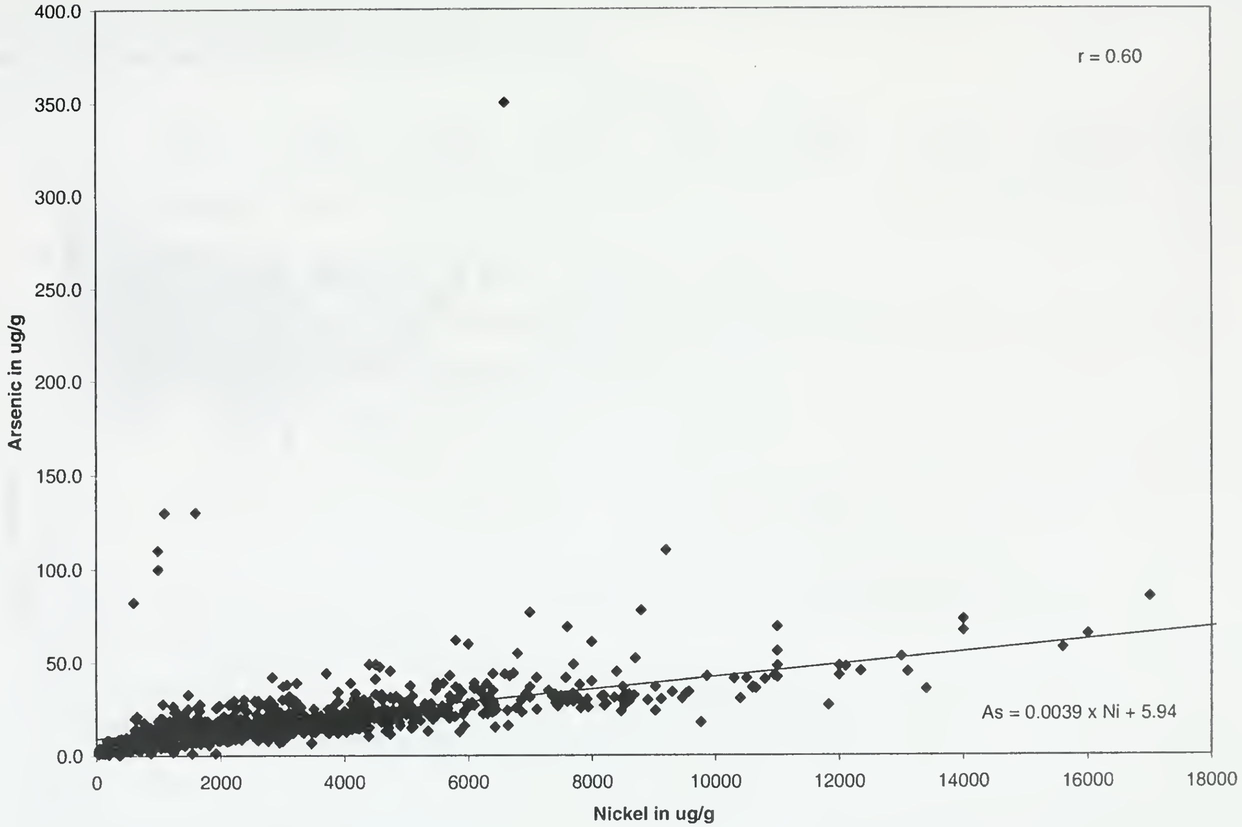


Figure C2: Relationship between arsenic and nickel in soil for all depths.

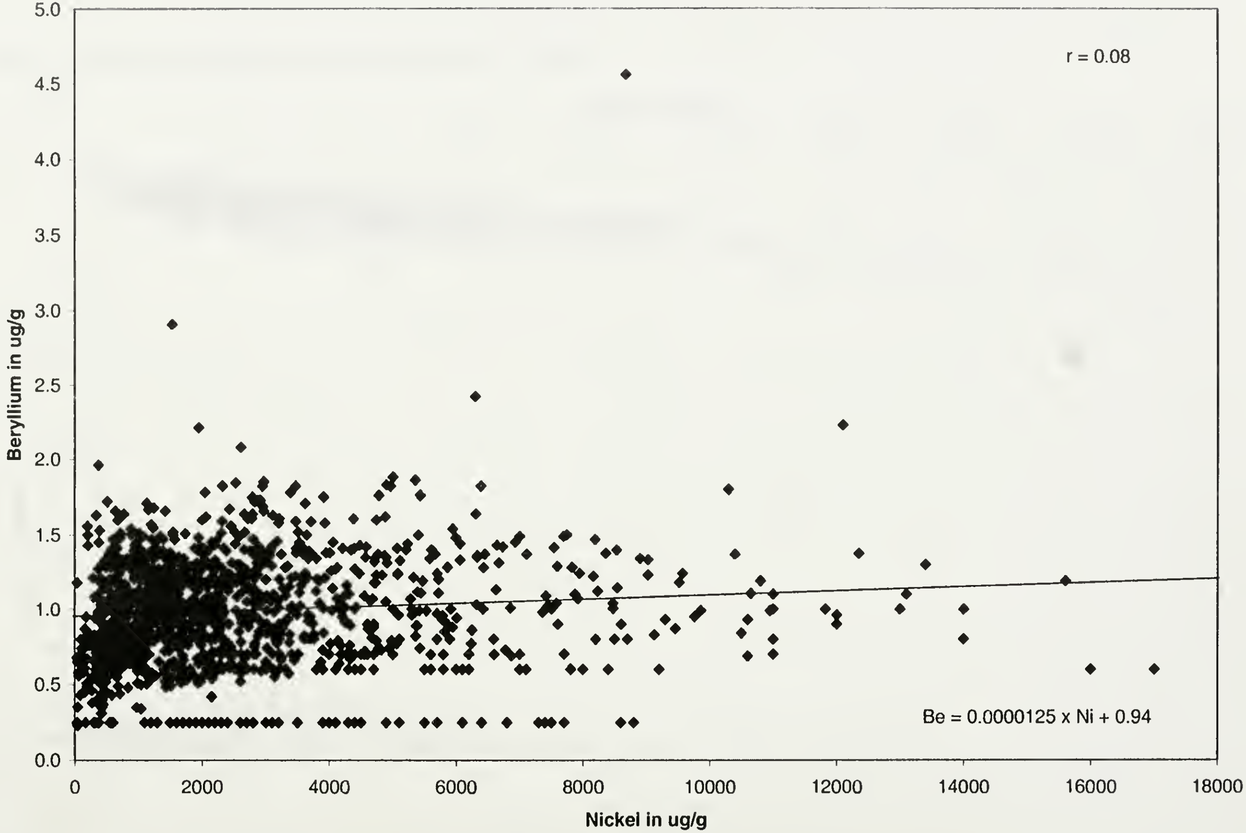


Figure C3: Relationship between beryllium and nickel in soil for all depths.

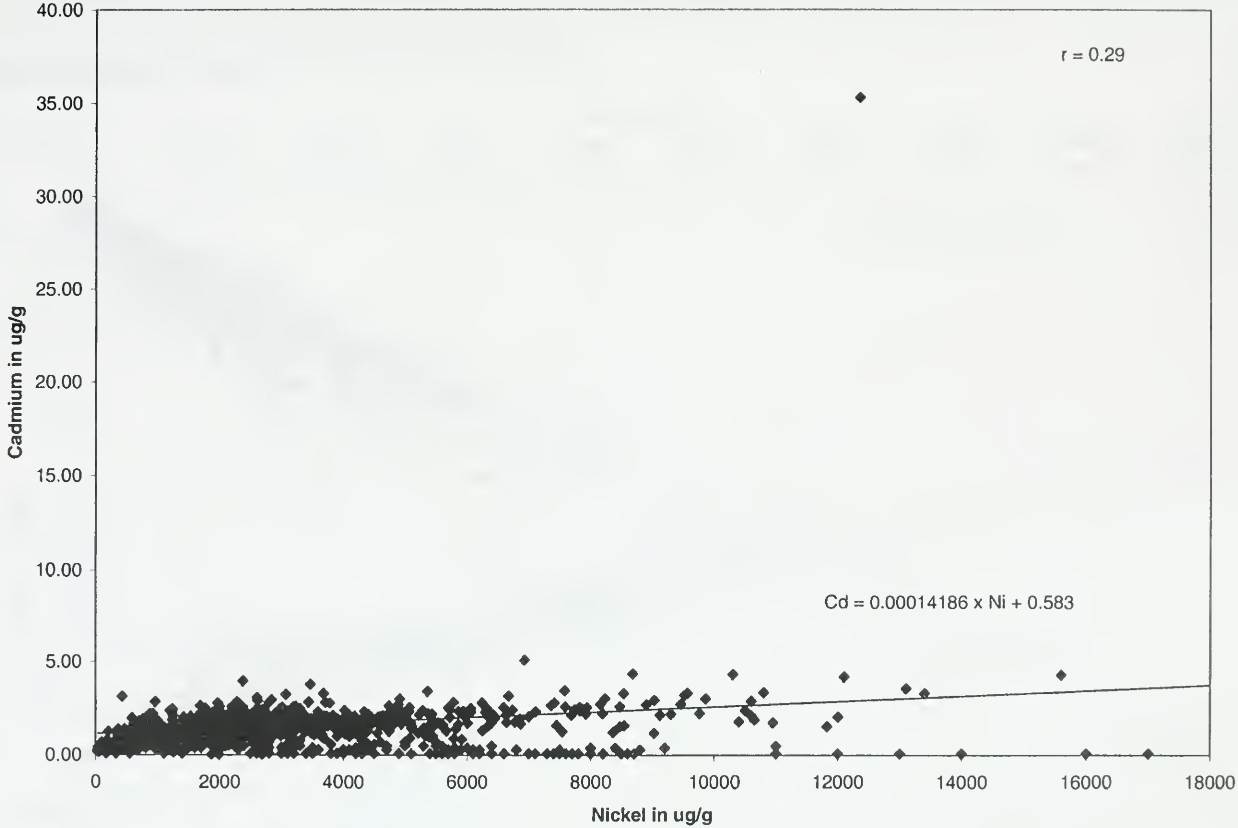


Figure C4: Relationship between cadmium and nickel in soil for all depths.

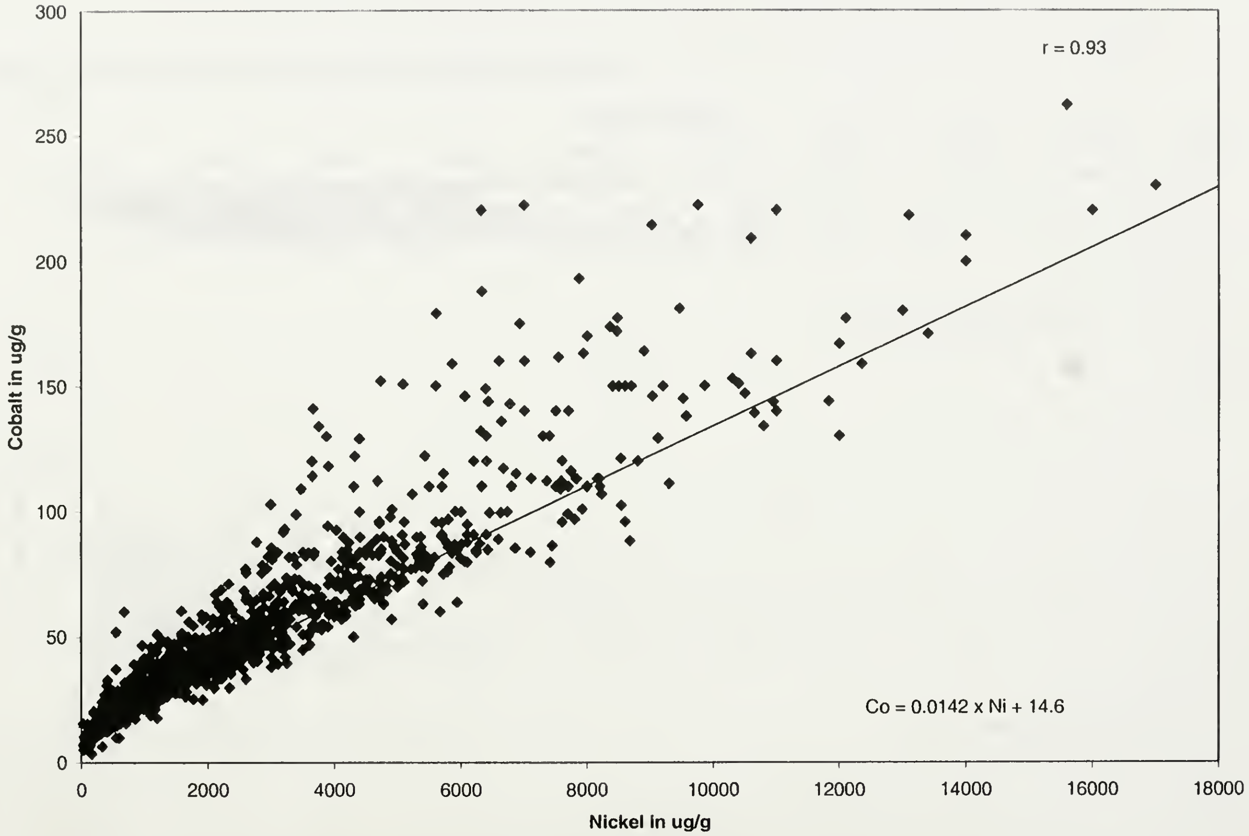


Figure C5: Relationship between cobalt and nickel in soil for all depths.

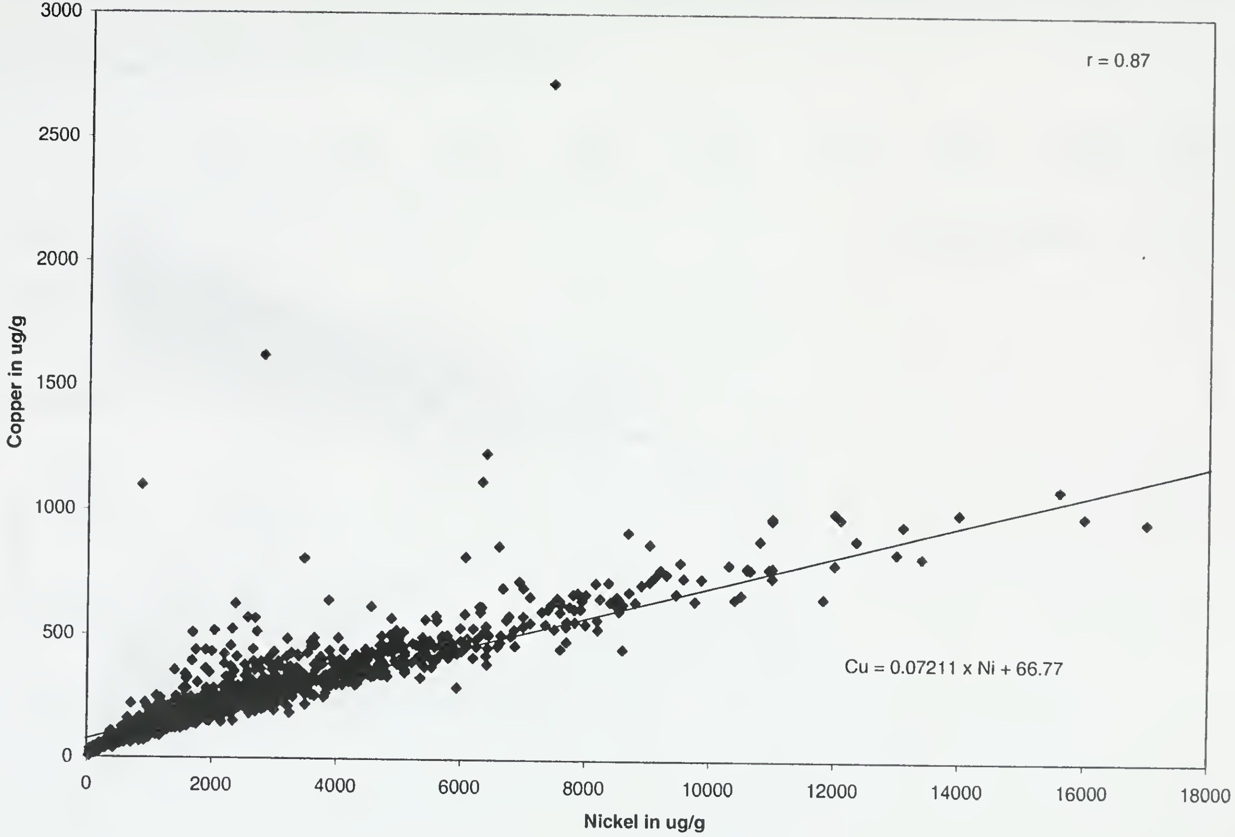


Figure C6: Relationship between copper and nickel in soil for all depths.

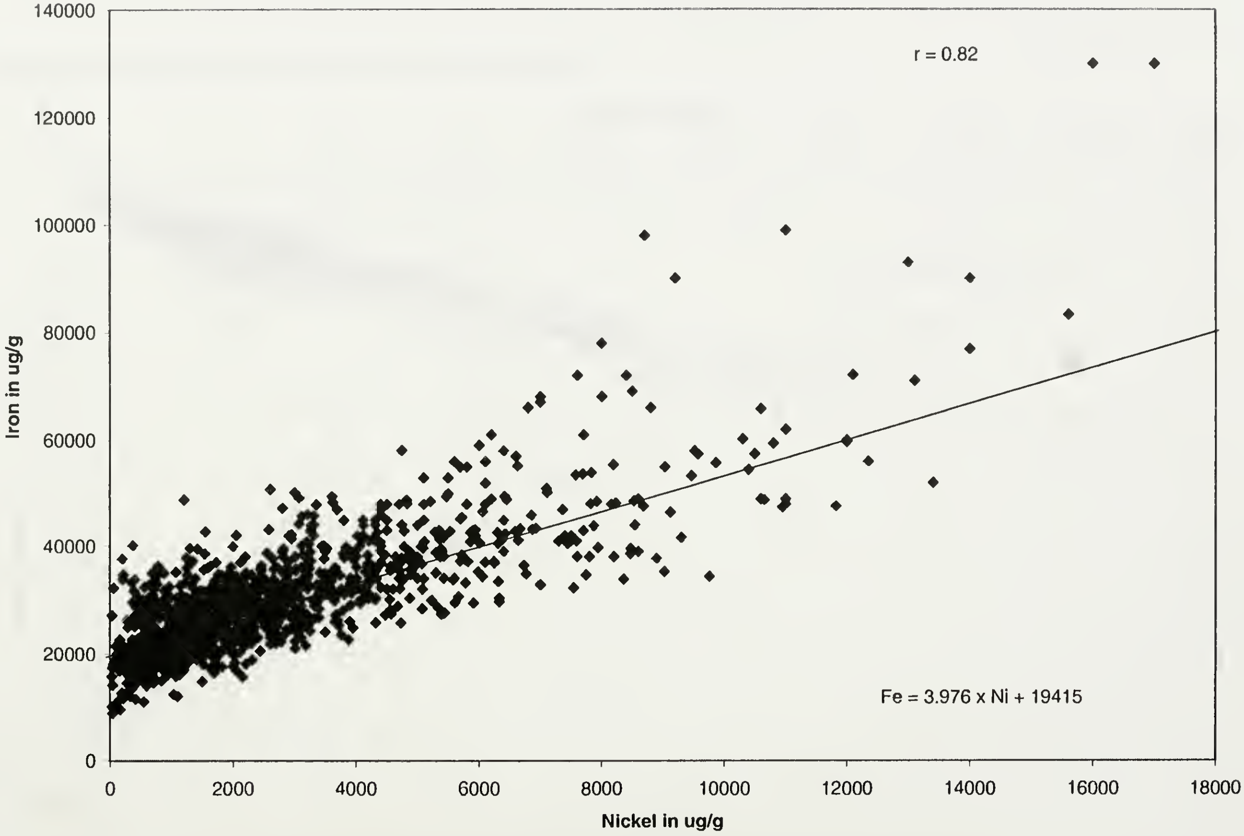


Figure C7: Relationship between iron and nickel in soil for all depths.

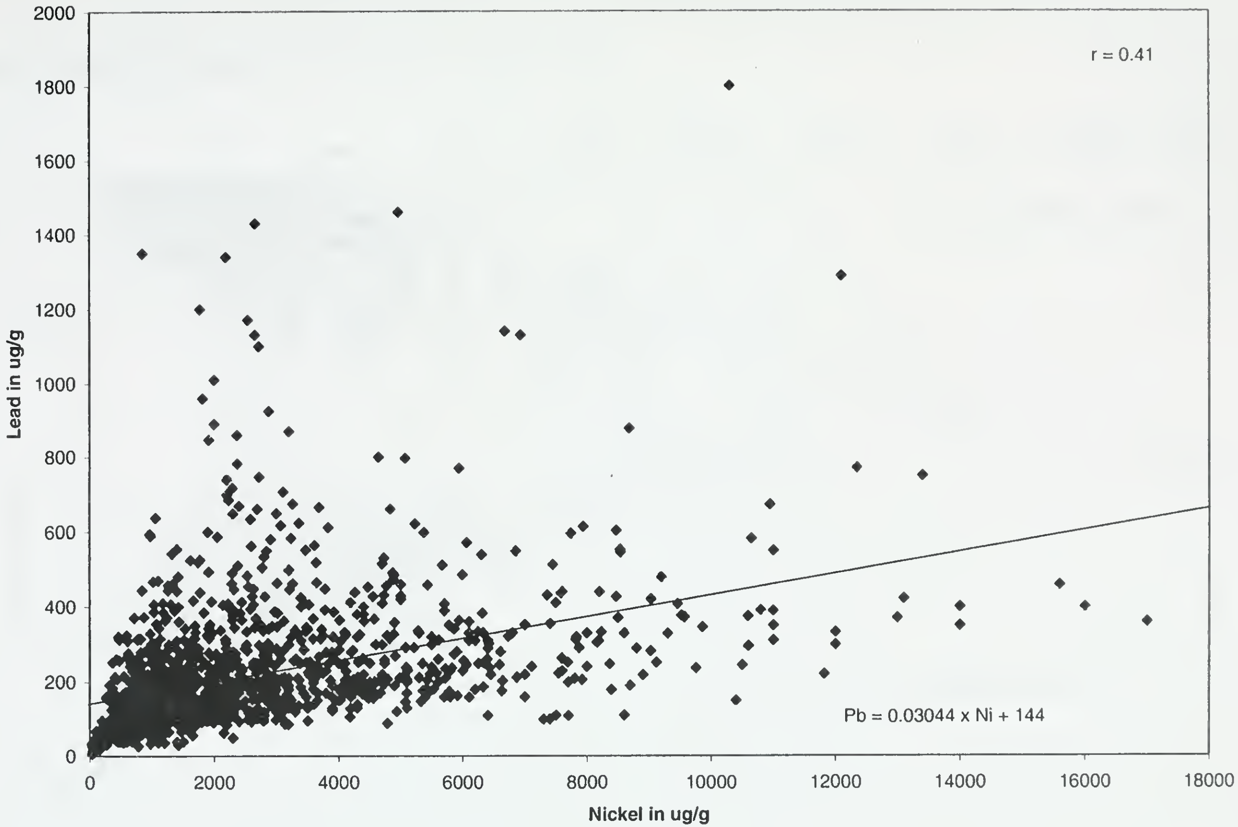


Figure C8: Relationship between lead and nickel in soil for all depths.

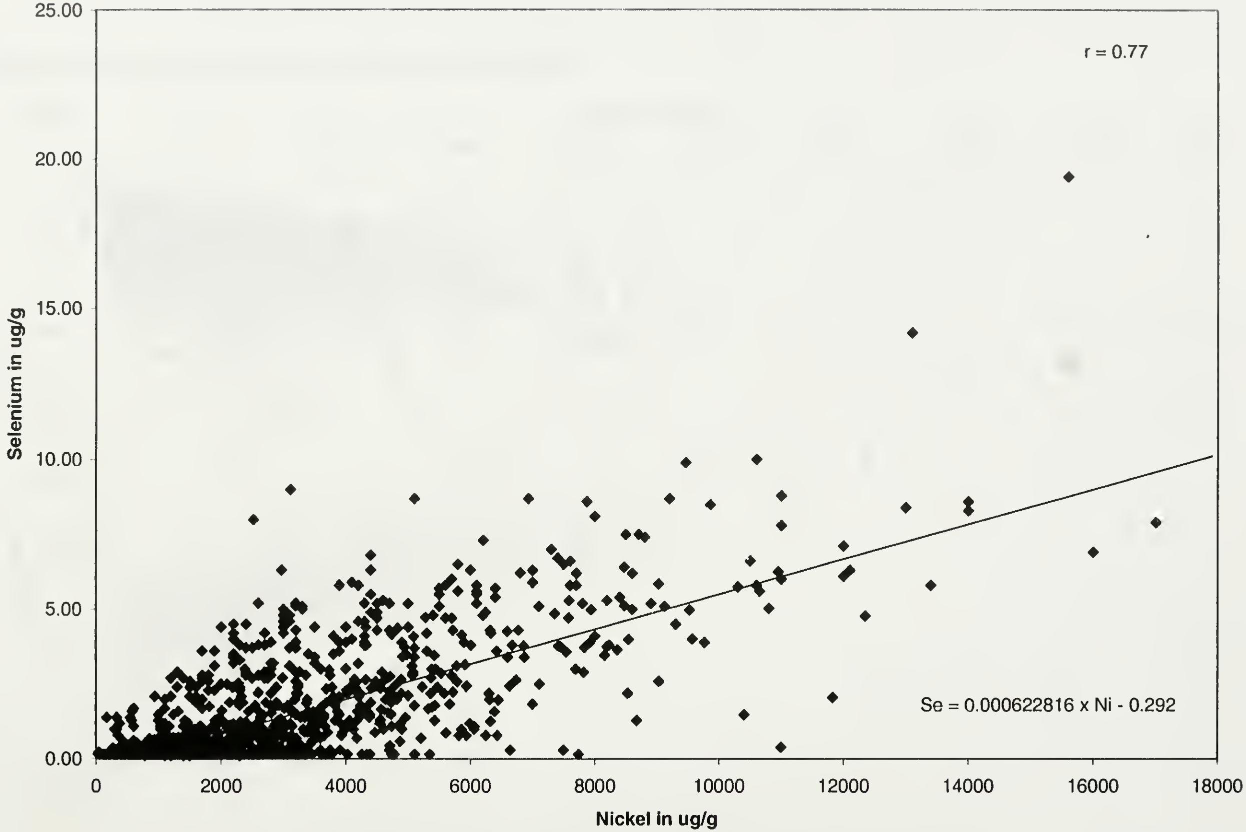


Figure C9: Relationship between selenium and nickel in soil for all depths.

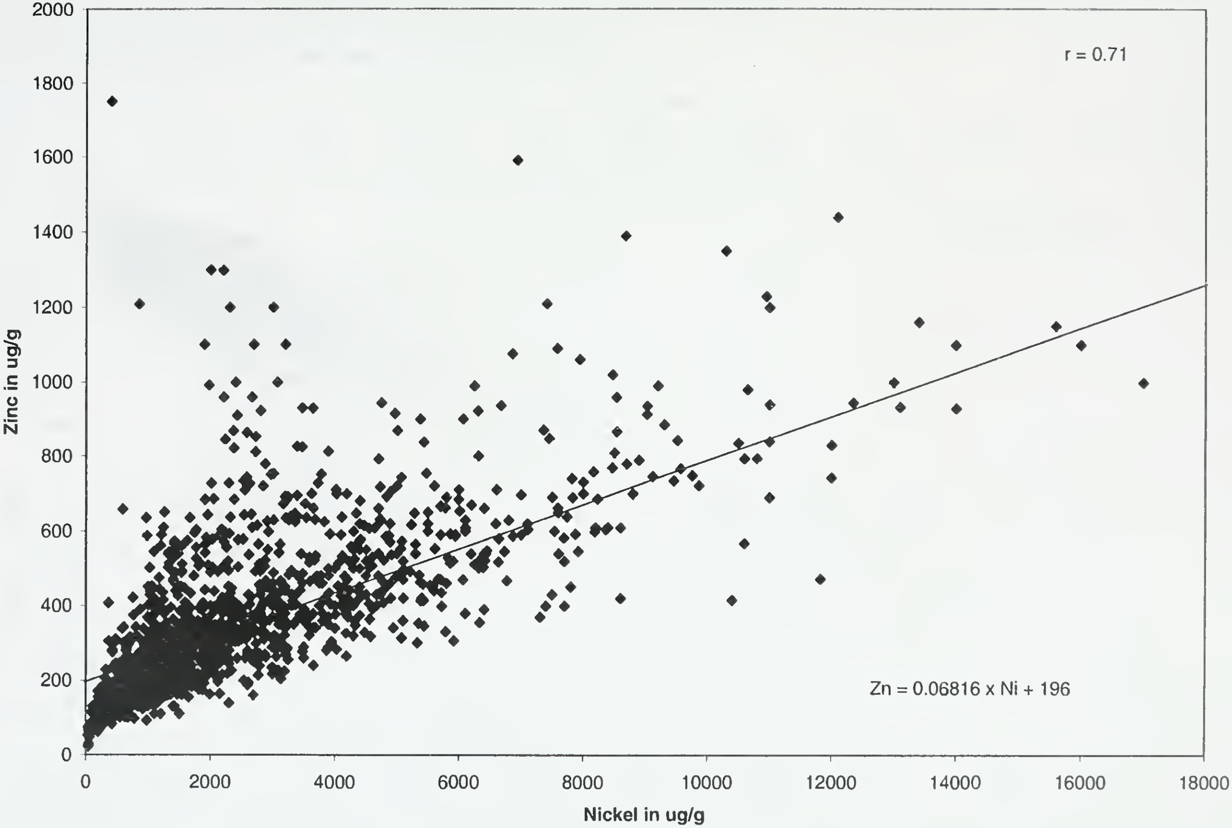


Figure C10: Relationship between zinc and nickel in soil for all depths.

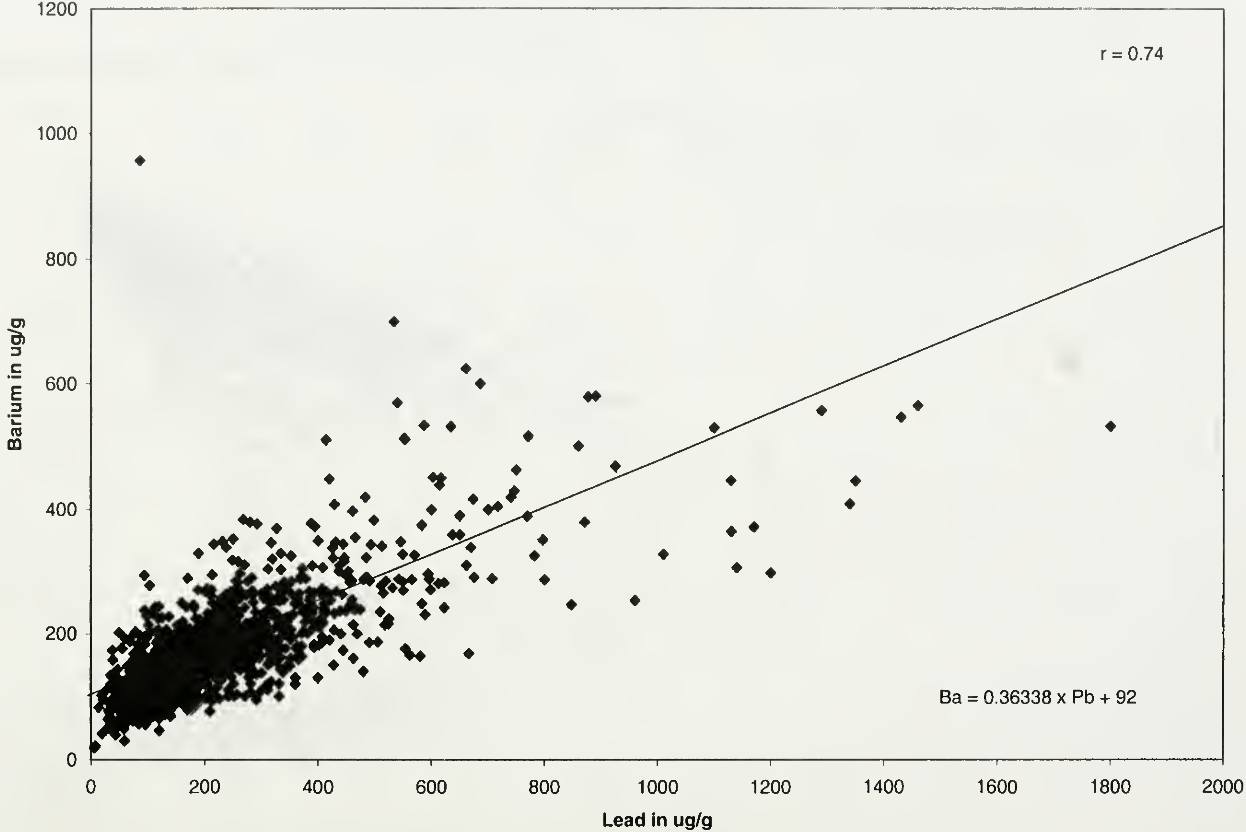


Figure C11: Relationship between barium and lead in soil for all depths.

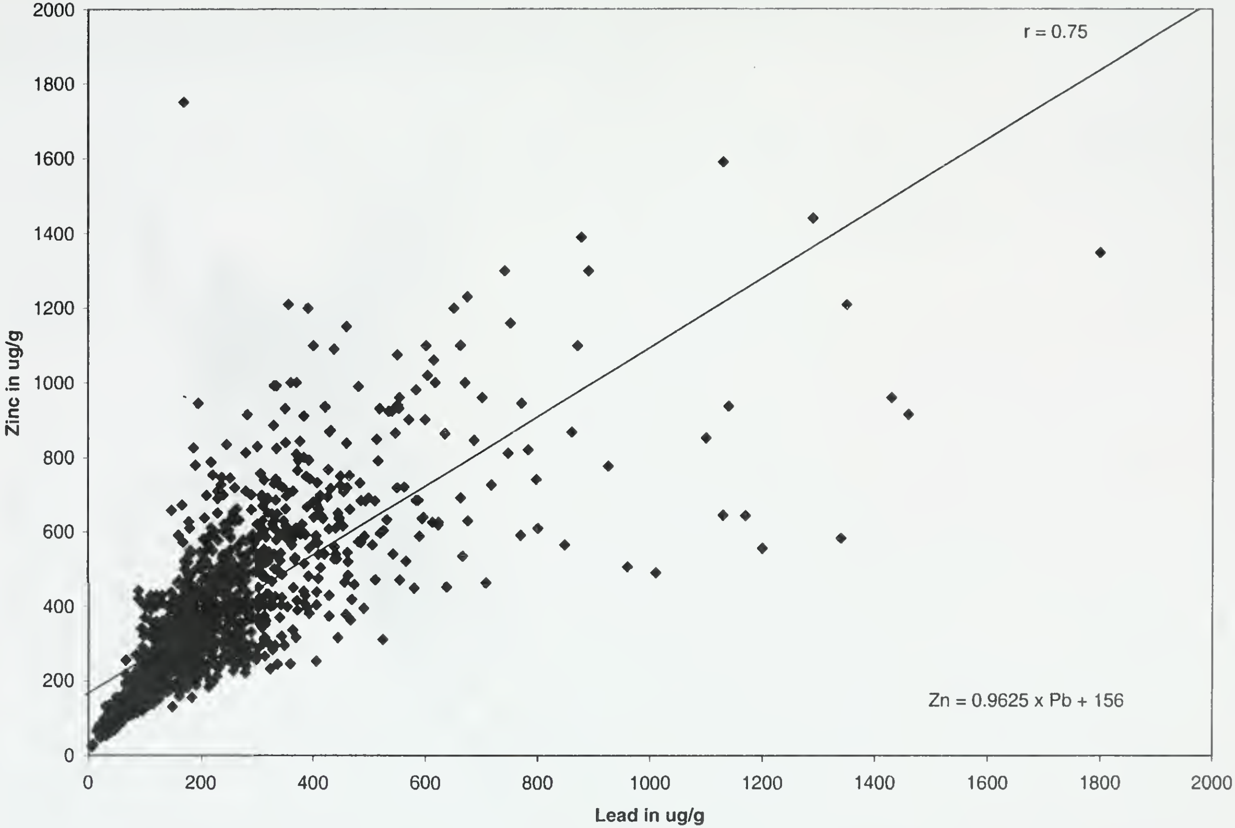


Figure C12: Relationship between zinc and lead in soil for all depths.

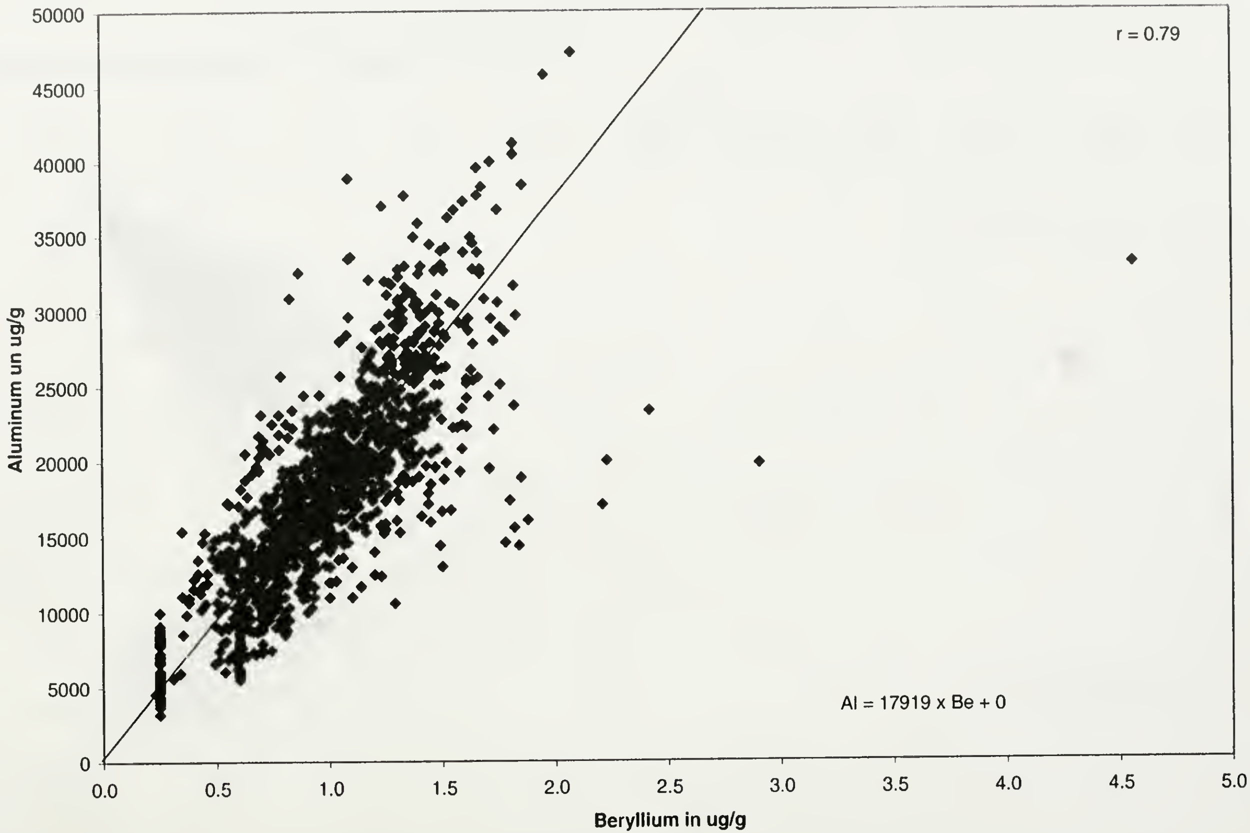


Figure C13: Relationship between aluminum and beryllium in soil for all depths.

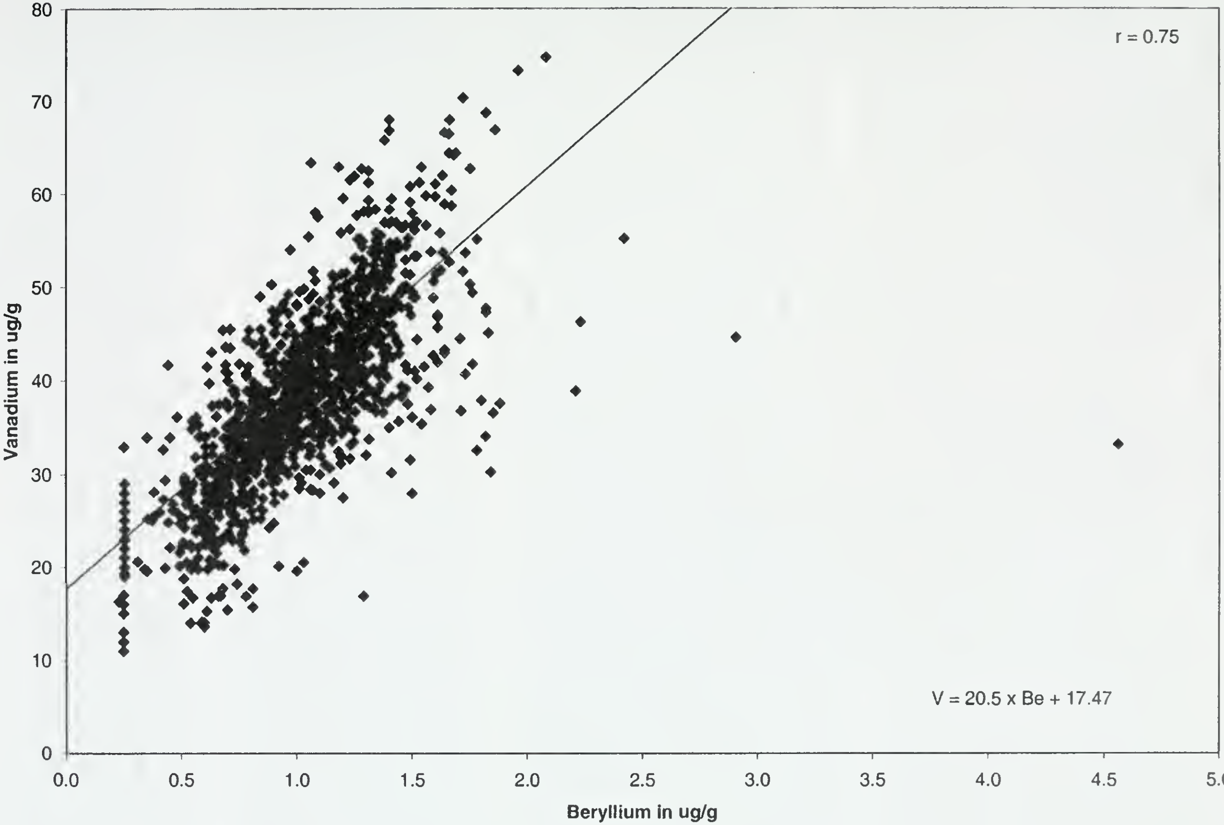


Figure C14: Relationship between vanadium and beryllium in soil for all depths.

Appendix D
Derivation and Significance of the MOE Soil Remediation Criteria (Clean-up Guidelines)

The MOE soil clean-up *Guidelines* have been developed to provide guidance for cleaning up contaminated soil. The *Guidelines* are not legislated Regulations. Also, the *Guidelines* are not action levels, in that an exceedence does not automatically mean that a clean-up must be conducted. The *Guidelines* were prepared to help industrial property owners decide how to clean-up contaminated soil when property is sold and/or the land-use changes. Most municipalities insist that contaminated soil is cleaned up according to the MOE *Guidelines* before they will approve a zoning change for redevelopment, therefore, even though the *Guideline* is voluntary most industrial property owners and developers are obliged to use it. For example, the owner of an industrial property who plans to sell the land to a developer who intends to build residential housing can use the *Guideline* to clean up the soil to meet the residential land-use criteria. In this way previously-contaminated industrial land can be re-used for residential housing without concern for adverse environmental effects.

The *Guideline* contains a series of Tables (A through F), each having criteria for soil texture, soil depth, and ground water use for various land-use categories (eg, agricultural, residential, industrial). Table F *criteria* reflect the upper range of background concentrations for soil in Ontario. An exceedence of Table F indicates the likely presence of a contaminant source. Tables A through E *criteria* are effects-based and are set to protect against the potential for adverse effects to human health, ecological health, and the natural environment, whichever is the most sensitive. By protecting the most sensitive parameter the rest of the environment is protected by default. The *Guideline criteria* take into consideration the potential for adverse effects through direct contact, and through contaminant transfer from soil to indoor air, from ground water or surface water through release of volatile gases, from leaching of contaminants in soil to ground water, or from ground water discharge to surface water. However, the *Guideline criteria* ***may not*** ensure that corrosive, explosive, or unstable soil conditions will be eliminated.

If the decision is made that remedial action is needed, the *criteria* in Tables A to F of the *Guideline* can be used as clean-up targets. In some cases, because of economic or practical reasons, it may not be possible to clean up a site using the generic *criteria* in Tables A to F. The *Guideline* provides a process, called a *site specific risk assessment*, which is used to evaluate the soil contamination with respect to conditions that are unique to the contaminated site. In a *site specific risk assessment* the proponent examines all the potential pathways through which the contamination may impact the environment and must demonstrate that because of conditions unique to that site the environment and human health will not be adversely effected if contamination above the generic *criteria* in Table A to E is left in place.

When contamination is present and a change in land-use is not planned, for example residential properties and public green spaces near a pollution source, the *Guideline* may be used in making decisions about the need for remediation. This is different from the previously described situation where a company that caused contamination on their own property decides to clean up the soil, usually at the insistence of the municipality who will not approve a zoning change unless remediation is conducted. Decisions on the need to undertake remedial action when the *Guideline criteria* are exceeded ***and*** where

the land-use is not changing are made on a site by site basis using *site specific risk assessment* principals and are usually contingent on the contaminants having caused an adverse environmental effect or there is a demonstrated likelihood that the contamination may cause an adverse effect. Because of the long history of industrial operation and our practice of living close to our work place the soil in many communities in Ontario is contaminated above the effects-based *criteria* in the MOE *Guidelines.* In practice, remediation of contaminated soil on privately-owned residential property and public green spaces has only been conducted in communities when the potential for adverse health effects has been demonstrated.

The soil clean-up *Guidelines* were developed from published U.S. EPA and Ontario environmental data bases. Currently there are criteria for about 25 inorganic elements and about 90 organic compounds. Criteria were developed only if there were sufficient, defendable, effects-based data on the potential to cause an adverse effect. All of the criteria address human health and aquatic toxicity, but terrestrial ecological toxicity information was not available for all elements or compounds. The development of these clean-up *Guidelines* is a continuous program, and criteria for more elements and compounds will be developed as additional environmental data become available. Similarly, new information could result in future modifications to the existing *Guidelines.*

For more information on the MOE's soil clean-up *Guidelines* please refer to the *Guideline for Use at Contaminated Sites in Ontario. Revised February 1997*, Ontario Ministry of Environment and Energy, PIBs 3161E01, ISBN 0-7778-6114-3, or go to the MOE web site at www.ene.gov.on.ca.

Part B: Human Health Risk Assessment

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1.0 Introduction

This document is part of a combined Standards Development Branch soil investigation (Part A) and health-based risk assessment report (Part B). The health-based risk assessment part of this report is designed to answer community health concerns raised by the discovery of elevated levels of nickel and other metals below the normal surface soil sampling depth (0-5 cm) on a Rodney Street property in June 2000. The soil metal concentrations were higher than previously measured (Part A).

While this study is health-based, it is not a community health study. This health-based risk assessment is directed at assessing exposure to selected metals in Rodney Street properties to evaluate whether health-based exposure limits are exceeded and whether there is an exposure level (or soil concentration) that warrants further actions (including soil remediation) to reduce exposure to identified soil metal concentrations. This approach takes a snapshot of current soil levels based on the most recent soil monitoring information as shown in the accompanying soil investigation (Part A).

For historical reasons and the proximity of the INCO metal refinery, the primary focus of the investigation was directed at the widespread and elevated levels of nickel in the community. Initially this study was targeted at performing a detailed human health risk assessment (HHRA) for this metal. However, as information on other metals became available, a need to assess the potential for health risks due to these other metals was indicated. A detailed HHRA for each of these other metals was performed. The other metals were initially selected for further study on the basis that their soil concentrations exceeded the residential soil quality criteria (*Table A*) of the Ministry's Guideline for Use at Contaminated Sites in Ontario (MOE, 1997). Exceedance of the *Table A* guidelines does not necessarily imply that exposure constitutes an undue risk to health. Several of the *Table A* guidelines are based on ecotoxicological effects. Health based *Table A* guidelines incorporate an adequate margin of safety and are set well below any concentration where health effects might occur.

Because of the extensive knowledge of risks related to arsenic and lead in soil, particularly through similar and more detailed risk assessments in other Ontario towns and cities, a careful analysis comparing levels , conditions and risk in these other situations to levels and conditions in the Rodney Street community allowed meaningful insight into the question of possible increased risk. Additionally, in the case of lead, a weight of evidence approach with consideration of various factors from the most recent scientific and regulatory literature, are used to support derivation of appropriate intervention levels.

1.1 Background

As described in Part A of this report, over 60 years of emissions (1918-1984) from the INCO nickel refinery have caused elevated surface soil concentrations of nickel, copper, and cobalt in a large area of the town of Port Colborne. The refinery ceased processing nickel concentrate in 1984. Based on extensive sampling conducted by the Phytotoxicology Section of the Standards Development Branch, MOE in 1998 and 1999 (Part A), soil nickel levels exceed the MOE background-based

guideline (43 µg/g[1]) up to 28 km downwind of the refinery over an area of 345 km^2. The MOE effects-based soil nickel guideline is exceeded up to 3 km downwind over an area of 29 km^2.

The guideline criteria for Ni, Cu and Co are all based on phytotoxicity (vegetation effects). MOE and OMAFRA studies have documented metal toxicity to agricultural crops in the Port Colborne area. MOE toxicologists in conjunction with epidemiologists at the Regional Niagara Public Health Unit conducted a health risk assessment of soil nickel, copper, and cobalt levels in 1997. The conclusion of the health risk assessment was "*based on a multimedia assessment of potential risks, no adverse health effects are anticipated to result from exposure to nickel, copper, or cobalt in soils in the Port Colborne area. Furthermore, the review of population health data did not indicate any adverse health effects which may have resulted from environmental exposures.*" The maximum nickel concentration utilized in the multimedia exposure assessment was 9,750 µg/g.

The Rodney Street community, which is located due west of INCO, lies in a neighbourhood that has been directly impacted by historical stack emissions. Also, because of its close proximity to the refinery, the Rodney Street community was also subject to extensive fugitive emissions from the refinery during the early years prior to the construction of a stack (e.g. the period between 1918 and 1929). Previous MOE surface soil sampling found that soil Ni concentrations averaged less than 5,000 *u*g/g in this area ; however, very little depth sampling (greater than 5 cm depth) was conducted in the Rodney St. area. Previously, the highest soil Ni concentration found at depth (5-10 cm depth) was 2,750 *u*g/g.

Further sampling and analysis of soil samples from the Rodney Street community in June of 2000 showed that soil Ni concentrations at depth (10-15 cm depth) were very high (17,000 *u*g/g). In addition, Cu, Co, As, Pb and Zn at depth, also exceeded corresponding MOE soil remediation guideline criteria.

As a result of the findings for the Rodney St. property, the Niagara District Medical Officer of Health requested that the remaining residential properties on Rodney St. be sampled as well. This additional sampling of front and back yards was completed in October, 2000. The results of the October 2000 soil sampling are discussed in Part A.

1.2 Purpose and Scope

A human health risk assessment of the elevated metals concentrations found in the soil in the Rodney Street area of Pt. Colborne, Ontario was conducted by Standards Development Branch, MOE. The health risk assessment was peer reviewed by an international panel of peer reviewers prior to public release. There is considerable public and media interest in the assessment and a peer review has assisted in improving the credibility and acceptability of the study.

MOE adopted a risk assessment framework to evaluate the environmental and human health risks of metals in Rodney Street community soils.The risk assessment paradigm which has dominated

1 Because the assessment of potential risks requires that intakes be estimated in µg/day, all soil concentration units used in the main report are expressed on a µg/g basis. This measure is equivalent to 0.000001g/g, 1mg/kg and 1 ppm

the regulatory decision making processes for the past two decades is the one promulgated in the 1983 U.S. NRC document "Risk assessment in the federal government: Managing the process" (NRC, 1983). This risk assessment paradigm and local variations on its theme has been adopted worldwide. As well as U.S. agencies, it is used by Canada and the Provinces, WHO and jurisdictions in most countries. Detailed methodologies for interpreting toxicological information and the various exposure pathways are extensive and are constantly being updated.

The human health risk assessment makes use of environmental monitoring data and recent toxicological information to estimate exposures and potential health effects. It examines current toxicological information to determine the types of health effects which have been reported following exposure to each of these metals (***hazard identification***), and to identify the levels of exposure at which the reported effects were manifested (***dose-response assessment***). It also makes use of multi-pathway modelling to estimate the total exposure to each of these metals which are likely to occur (***exposure assessment***). It then combines the toxicological and exposure information to estimate the potential health effects which may occur (***risk characterization***). Each of these components, hazard identification, exposure assessment, dose-response assessment and risk characterization has been described in detail in previous health risk assessment reports which have evaluated potential health risks associated with exposures to various metals in the soils in Port Colborne (MOE, 1997) and other locations in Ontario (MOE, 1991; MOEE, 1994, MOE, 1998).

The human health risk assessment includes the following components:

- *A multimedia approach*, which considers total exposure from all environmental media, was chosen to characterize the risk and to develop site-specific intervention levels for nickel and other metals in Rodney Street community soils. The approach recognizes that contaminants are present simultaneously in food, air, water, consumer products, soil or dust.

- *The exposure pathways of concern*, which include inhalation and incidental ingestion of soil particles derived from backyard soils, dermal contact with this soil and ingestion of backyard produce. In addition, exposures to supermarket food, ambient air and drinking water are estimated. The exposure model estimates daily intakes from all exposure pathways for different age classes (infant, toddler, child, teen and adult). Food basket data included recent Canadian Market Basket Survey information and backyard vegetable data collected from the Rodney Street area.

- *Important receptors,* which include, infants, toddlers, children, teens and adults. Toddlers (aged 7 months to 4 years) represent the most important receptor due to their increased exposures to soil and hand-to-mouth behaviour compared with other receptor age groups.

- *Assessment of the bioavailability of nickel (and other metals) from soil.* The bioaccessibility of nickel (and other metals) in soil was investigated using a simulated stomach acid leach test data.

- *Dermal exposure to nickel (and other metals)*. The dermal exposure pathway was examined as an intake pathway, however, even though contact dermatitis (for nickel) is a relatively common occurrence in the general population (i.e., due to contact with coinage, jewelry and

stainless steel objects), oral and dermal exposure limits for this endpoint have not been developed by other regulatory agencies.

- *Toxicological assessment of nickel (and other metals).* The dose-response assessment assessed cancer and non-cancer exposure limits based on nickel species characterization (other metals were not speciated).

- *Development of health-based site-specific intervention levels.* An important output of the risk assessment process are intervention levels. These are tools for evaluating and cleaning up contaminated soils.

1.3 Organization of the Report

The risk assessment for antimony, beryllium, cadmium, cobalt, copper and nickel (Hazard identification (identifying metals of concern), Toxicity assessment, Exposure Assessment, Risk Characterization), identification of soil intervention levels, discussion of uncertainties, and, recommendations and conclusions for nickel (and other metals) form the main body of the report. Information on Environmental Monitoring of Metals in the Rodney Street community and Port Colborne; Toxicity Assessment (toxicity profiles); Detailed Estimates of Daily Intakes of Metals; Estimating Daily Intakes of Metals from Supermarket Food; Simulated Stomach Acid Leach Test Results; Estimating Backyard Vegetable Consumption for the Rodney Street community; and Dermal Uptake Coefficients for Metals are found in appendices 1 to 7.

2.0 Identifying Metals of Concern

An extensive sampling program has been carried out for the homes in the Rodney Street community in Port Colborne (Part A). The monitoring program identified ten metals that are present in the soil at levels that exceed the current Ministry of the Environment guidelines for medium fine textured soil in a residential community (MOE, 1997) The range of reported concentrations for each of the ten metals is listed in Table 2-1. The respective MOE *Table A* criteria are also listed. Because this assessment focuses on human health, metal levels were also compared to the human health specific criteria originally developed for the MOE *Table A* which are listed in the *Rationale Document* which is one of three supporting documents for the MOE *Guideline*(MOE, 1996). The data in Table 2-1 shows that for seven of the ten metals including; antimony, arsenic, beryllium, cadmium, copper, lead and nickel, the highest reported concentrations exceed both the MOE *Table A* criteria and their respective human health criteria. For the remaining three metals, cobalt, selenium and zinc, the maximum levels reported in Rodney Street community soil are below their respective human health based criteria. Based on this, cobalt, selenium and zinc would not be expected to be human health concerns for the residents of the Rodney Street community. However, the previous risk assessment undertaken by the MOE included cobalt as a metal of concern. Therefore cobalt has been carried through the current assessment of exposure and risk. Selenium and zinc have not been carried through to the detailed risk assessment because the screening assessment has shown that these metals are not present in soil in sufficient quality to represent a potential human health concern. Based on the screening of metals shown in Table 2-1, eight metals have identified for inclusion in the detailed assessment of exposure and risk for the Rodney Street community.

Table 2-1: Summary of Soil Data for the Rodney Street Area

Metal	Concentration in Soil (µg/g)[1]				MOE Cleanup Criteria[2] (µg/g)	
	Minimum	Median	Average	Maximum	Guideline Criterion	Human Health Criterion
Antimony	0.28	0.20	1.20	91.1	13	13
Arsenic	0.60	12.70	15.90	350	25	-
Beryllium	0.23	0.97	0.97	4.56	1.2	0.37
Cadmium	0.14	1.09	1.20	35.33	12	14
Cobalt	3.50	39.80	50.7	262	50	2,700
Copper	4.40	200	250	2,720	300	1,100
Lead	5.90	179	223	1,800	200	200
Nickel	34.60	1,800	2,544	17,000	200	710
Selenium	0.23	0.29	1.29	19.40	10	320
Zinc	23.00	314	370	1,750	800	16,000

1: (0-30 cm; based on 1378 sample points)

2: Table A/B criteria for metals in residential/parkland soil for medium/fine textured soil

For two of the eight metals; arsenic and lead, the MOE has undertaken detailed assessments of exposure and risk in communities similar to the Rodney Street community (MOE, 1991, MOE, 1995). The results of these previous assessments have been used to develop management strategies

for arsenic and lead in the Rodney Street area of Port Colborne. These strategies are presented in the *Conclusions and Recommendations* section of the report (Section 7.0). Therefore, the human health risk assessment has focused on the remaining 6 metals. The detailed exposure assessment used the highest reported concentration of each metal in the soil from the Rodney Street area. The metals carried through to the risk assessment, and the soil concentrations used in the assessment are summarized in Table 2-2.

Table 2-2: Metals Considered in the Exposure Assessment

Metal	Concentration (μg/g)
Antimony	91.1
Beryllium	4.56
Cadmium	35.33
Cobalt	262
Copper	2,720
Nickel	17,000

3.0 Toxicity Assessment

The screening of chemicals in the soil in the Rodney Street area identified eight metals of potential concern (Section 2.0). A detailed toxicity assessment for each metal is provided in Appendix 2. This toxicity assessment briefly outlines the toxicological effects that have been reported to be associated with inhalation, ingestion and dermal contact exposures to antimony, arsenic, beryllium, cadmium, cobalt, copper, lead and nickel, and identifies whether each metal should be considered as a carcinogen or a non-carcinogen. The type of exposure limit selected is dependent upon whether a compound is considered to be non-carcinogenic or carcinogenic.

The toxicological profiles were not used to develop exposure limits for exposure routes where no exposure limits are available, nor were they used to critically review and/or modify currently existing exposure limits.

A summary of the information contained in Appendix 2 is provided in Table 3-1 and Table 3-2. For each metal, the selected reference dose, toxicological end-point and reference to the appropriate section of Appendix 2 is provided. These exposure limits have been used in conjunction with the exposure estimates (Section 4.0) to characterize potential risks (Section 5.0) associated with exposures to each of the metals in residential soil in the Rodney Street community.

Table 3-1: Exposure Limits and Toxicological Endpoints for Non-Carcinogenic Effects

Compound	Route	Non-Cancer Endpoints		Appendix Reference
		RfD/RfC	Endpoint	
Antimony	Oral	0.4 µg/kg-day	decreased longevity and altered blood chemistry in rats	A2-1
	Inhalation	0.2 µg/m³	pulmonary toxicity in rats	
Beryllium	Oral	2 µg/kg-day	intestinal lesions in dogs	A2-3
	Inhalation	0.02 µg/m³	beryllium sensitization in human populations	
Cadmium	Oral	1 µg/kg-day	kidney damage in humans	A2-4
	Inhalation	-1		
Cobalt	Oral	60 µg/kg-day	kidney effects in renally compromised patients	A2-5
	Inhalation	0.03 µg/m³	squamous metaplasia in rodent larynx	
Copper	Oral	140 µg/kg-day	liver damage	A2-6
	Inhalation	2.4 µg/m³	inhalation chronic reference exposure limit	
Nickel	Oral	20 µg/kg-day	decreased body and organ weights in rats	A2-8
	Inhalation	-		

- no value available

Table 3-2: Cancer Potency Values for Contaminants of Concern

Compound	Route	Cancer Endpoints			Appendix Reference
		UR[1]	SF[2]	Endpoint	
Beryllium	Oral	-[3]			A2-3
	Inhalation	0.0024 $(\mu g/m^3)^{-1}$		lung cancer in humans	
Cadmium	Oral	-			A2-4
	Inhalation	0.0018 $(\mu g/m^3)^{-1}$		lung cancer in cadmium workers	
Nickel	Oral	-			A2-8
	Inhalation	0.00024 $(\mu g/m^3)^{-1}$		lung cancer in nickel refinery workers	

1. UR = Unit Risk = risk per (µg/L) oral or ($\mu g/m^3$) in air.
2. SF = Cancer slope factor = risk per dose body weight ie per (µg/kg-day)
3. - no value available

4.0 Exposure Assessment

The presence of elevated levels of several metals in the soil of residential properties in the Rodney Street community in Port Colborne has raised concerns regarding exposures experienced by residents and the potential human health effects associated with these exposures. The current assessment has been undertake to provide interested/concerned parties with estimates of the metal exposures that could be experienced by residents of the Rodney Street community. People living in the Rodney Street community, like all residents of Ontario, are exposed to metals from a number of sources including, processed food, drinking water and air. In addition to these general exposures that are common to the population of Ontario, the residents of the Rodney Street community can be exposed to metals in the soil and in home grown produce. A detailed assessment was undertaken for people living in the Rodney Street community to develop estimates of the total daily exposure experienced by people of all ages. Specific details of exposure assessment methodologies are found in Appendices 3 to 7.

4.1 Receptor Identification

4.1.1 Identification of Potential Receptors

The Rodney Street community in Port Colborne is a residential neighbourhood with single family detached homes. The properties are municipally serviced with domestic water that is not derived from groundwater in the area. People living in the homes in the Rodney Street community will be exposed to the metals present in the soil, but not to any metals that may be present in the groundwater in the area. Because this is a residential community, anybody living in the area can be expected to come into contact with metals present in the soil in the neighbourhood. A list of all of people who can be expected to be exposed to metals in the soil is provided in Table 4-1.

Table 4-1: Potential Human Receptors In The Rodney Street Community

Potential Receptor	Activity Assumptions
Infant (0 - 6 months of age)	Assumed to be present on residential property for 24 hour per day every day over each phase of a 70 year life-time. All ingested soil is assumed to contain the highest reported level of each metal in soil in the Rodney Street community. All soil assumed to adher to skin every day of the year. All backyard produce consumed assumed to contain highest level found. All drinking water assumed to contain highest concentration found in distribution system. All inhaled air is assumed to contain the highest reported annual average level of each metal measured in Port Colborne or nine other sites in Ontario.
Toddler (7 months - 4 years)	
Child (5 - 11 years)	
Teen (12 - 19 years)	
Adult (20+ years)	

4.1.2 Identifying Exposure Pathways

People living in the homes in the Rodney Street community can be exposed to the metals in the soil by one of three different routes including; inhalation, ingestion and dermal contact. There are several things that can contribute to the exposures experienced by each of these routes. For example, the ingestion of soil and the consumption of backyard produce would contribute to ingestion exposures, while skin contact with soil would contribute to dermal contact exposures. Each of these possibilities, known as *exposure pathways*, contribute to the total daily exposures experienced by people living in these homes. The potential exposure pathways that could contribute to these exposures are listed in Table 4-2, along with the rationale for their inclusion in the assessment. Table 4-2 also identifies exposure pathways that have not been considered and provides rationale for their exclusion from the process. In order to estimate any potential risks associated with exposure to the metals in the soil, the contribution that each included pathway makes to the total daily exposure must be assessed.

Table 4-2: Possible Human Exposure Pathways In The Rodney Street Community

Media	Exposure Route	Pathway	Retained	Rationale
Air	Inhalation	Inhalation of metals on re-entrained soil and dust in indoor air and outdoor air	Yes	The exposure assessment has not distinguished between indoor and outdoor air. The current assessment assumes that a person will be exposed to the same level of nickel and other metals in indoor and outdoor air and that the highest annual average from air monitoring data will be representative.
Soil	Ingestion	Ingestion of soil	Yes	The ingestion of metals in soil represents a potential exposure pathways for people living in the homes in the in Rodney Street community
		Uptake into plants and consumption of plants	Yes	Fruits and vegetables grown in backyard gardens in the Rodney Street community properties may contain metals taken up from the soil. The consumption of this produce represents a potential exposure pathway for residents in the Rodney Street community.
		Uptake into animals through plants and consumption of animal products	No	The homes in the Rodney Street community are not used for the production of livestock. Therefore exposure to metals through the consumption of livestock raised in the Rodney Street community will not occur.
	Dermal Uptake	Dermal contact with soil	Yes	Exposure to metals through skin contact with metal bearing soil is a potential exposure pathway for residents in the Rodney Street community.
Groundwater	Ingestion	Ingestion of metals in water derived from groundwater	No	Groundwater is not used as a source of domestic supply.
	Dermal Uptake	Dermal Contact with metals in the groundwater.	No	The groundwater will not be used for any purpose on-site.

4.1.3 Identifying Receptor Parameters

In addition to knowing who will be exposed to the metals in the soil and what routes contribute to the total exposure, it is necessary to have an understanding of amount of exposure that could be expected to people in each of the age groups identified in Table 4-1. For example, the amount of soil ingested will determine the level of direct exposure to metals in the soil, and the amount of air inhaled in a day will govern the inhalation exposures experienced. These factors, and others, known as *receptor parameters* will govern the exposures experienced by the residents of the Rodney Street community. A list of the receptor parameters including; body weight, inhalation rate, drinking water intake, soil ingestion, soil adhesion to skin, and consumption rates for backyard garden vegetables, used to assess exposures for the residents of the Rodney Street community are presented in Table 4-3. A detailed discussion of the selection and derivation of the values listed in Table 4-3 is provided in Appendix 3 of the report.

Table 4-3: Receptor Parameters Used to Estimate Daily Exposures

Parameter	Units	Infant	Toddler	Child	Teen	Adult	Source
		0 - 0.5 y	0.5 - 4 y	5 - 11 yrs	12 - 19 yrs	20+	
Years in Age Group	years	0.5	4.5	7	8	50	CEPA, 1994c
Body Weight	kg	8.2	16.5	32.9	59.7	70.7	O'Connor, 1997
Inhalation Rate	m^3/day	3.2	14.6	20.3	23.1	22.9	O'Connor, 1997
Drinking Water Intake	L/day	0.3	0.6	0.8	1	1.5	O'Connor, 1997
Soil Ingestion	g/day	0.035	0.08	0.08	0.02	0.02	MOE, 1991[1]
Soil Adhesion to Skin	g/day	2.2	3.5	5.8	9.1	8.7	Health Canada, 1995
Backyard .Root Veg	g/day	8.18	10.3	15.9	22.4	19.3	MOE, 1995
Backyard .Other Veg	g/day	7.09	6.6	9.65	11.8	14.1	MOE, 1995
Supermarket Food	g/day	822	1478	1798	1945	1598	CEPA, 1994c

1 Soil ingestion rates typically used by MOE is assessing risks associated with chemicals in soil

4.1.4 Exposure Assessment Assumptions

The objective of the assessment is to provide exposure estimates that are representative of the maximum exposures that could be experienced by the residents of the Rodney Street community. A list of the assumptions used in this assessment and the effect that each will have on exposure estimates is provided in Table 4-4.

4.2 Metal Concentrations in Environmental Media

As noted above, the risk assessment is intended to provide reasonable maximum estimates of exposure for residents in the Rodney Street community. Therefore the maximum level of each metal reported in drinking water, soil, and backyard garden vegetables have been used to assess potential exposures from these sources. Metal levels in ambient air are not based on the maximum reported levels, but rather on the maximum reported annual average value. The rationale for this is provided in Appendix 3. The concentrations of metals the various media are summarized in Table 4-5.

Table 4-4: Summary of Exposure Assessment Assumptions

Parameter	Assumption	Effect on Assessment
Residency Time	A person has been assumed to live in a residence every day for a full 70-year life-time (a total of 25550 days).	This approach over estimates all potential exposures because it does not allow for changes in exposure during the time when people would be away from the home.
Soil Ingestion	The rate of soil ingestion has been assumed to remain constant throughout the year. For each metal it was further assumed that all of the soil ingested in a day comes from the area of where the highest level of each individual metal was found. This assessment also assumed that surface soils are the only contributors to daily soil ingestion	This approach will over estimate soil ingestion exposures to metals because it assumes that people will have access to the soil 365 days per year. It does not allow for periods when access to the soil will not be possible due to snow cover of ground freezing. It also does not account for people moving about between areas of varying metal concentrations in the soil. However, year round soil ingestion should address the issue of indoor dust exposure.
Backyard Vegetable Consumption	Backyard vegetable consumption has been assumed to occur every day throughout the year. The amount of vegetables produced and consumed has been estimated based on previous studies conducted by the MOE in other communities in Ontario.	This assumption may over estimate potential exposures for people in the area who do not grow or consume home produce, or produce less than has been assumed in this assessment.
Skin Contact with Soil	The total amount of skin contact with soil was assumed to take place in the area of highest reported concentration for each metal. It was also assumed that dermal contact would occur every day 365 days per year, every year over a 70 year life-time. It was also assumed that once on the skin, soil would remain in place for a full 24 hours before it was removed by washing.	This approach will over estimate exposures that occur through skin contact. It does not account for periods during the year when access to the soil would be limited either through snow cover and/or ground freezing. It also does not account for soil being washed off the skin before the end of a 24 hour period.
Drinking Water Intakes	People living in the Rodney Street community were assumed to get all domestic water from the municipal supply. Exposures were also assumed to occur every day over a 70 year life-time. The highest level of each metal reported in the drinking water was assumed to be present in the drinking water over the entire 70 year exposure period.	Using maximum values will over estimate the drinking water exposures to metals for residents of the Rodney Street community. The maximum reported values for the 1996 to 1999 monitoring period range between 1.5 and 2-fold greater than the average levels reported over the same period (see Appendix 1).

Continued......

Table 4-4: Summary of Exposure Assessment Assumptions (continued)

Parameter	Assumption	Effect on Assessment
Supermarket Food	Daily food consumption estimates developed by Health Canada for the general population were assumed to be representative of the food consumption rates and patterns for residents of the Rodney Street community. For Rodney Street community residents, it was further assumed that any backyard garden produce consumed would be <u>in addition to</u> the daily intakes of supermarket food. That is; the Health Canada daily consumption estimates for root and other vegetable were not lowered to account for decreases in the intakes of supermarket produce when home produce was being used.	This approach will over estimate the daily intakes of metals from produce purchased at the supermarket. The estimated daily dietary intakes of metals from supermarket foods will be marginally over estimated using this approach.
Inhalation in Air	Inhalation exposure to metals in the air of Port Colborne have been assumed to occur over a 24 hour period. It has been assumed that the levels of metals in indoor air are the same as those found in ambient outdoor air. It was further assumed that a person would be exposed to the highest reported annual average level of each metal every day over a 70 year life-time. This approach also assumes that the levels of metals reported in the air are present as free metal and are not bound to particulate matter.	This assumption will over estimate inhalation exposures to metals. It does not account for differences in exposure that could be expected to occur in indoor air, where metal and particulate levels could reasonably be expected to be lower than those measured in outdoor air. Further, assuming a 70 year life-time residency does not allow for decreases in exposures that may occur when a person would be away from the Rodney Street community. This assumption also does not account for the bioavailability of the metal on the particulate. By assuming that the monitored levels represent free metal, and further assuming that all of this metal is available for absorption in the lung, the assessment over estimates actual doses.
Inhalation of Dust	This assessment has not directly considered the inhalation of metals on re-entrained dust particles. The assessment has used ambient air monitoring data for the metals of concern. In ambient air, metals are generally bound to particulate matter. Therefore ambient air monitoring results reflect the levels of metals bound to particulates in the air and provide a truer estimate of the levels of metals present in the air than measurement of particulate matter would.	Not directly considering the inhalation of metals on particulates does not compromise the assessment of exposure or risk because direct inhalation exposures to metals are being considered.

Metal levels in individual supermarket food items are not considered directly in the current assessment. Rather the exposure assessment has relied on estimates of the total daily dietary intake of each metal provided by regulatory agencies such as Health Canada. A detailed discussion of the derivation of the daily dietary intakes of metals for all age groups is provided in Appendix 4. These values have been used directly in the estimation of total daily intake for receptors in each age group.

The values listed in Table 4-5 have been used in conjunction with the daily dietary intake estimates for each metal to develop estimates of total daily exposure for all residents in the Rodney Street community.

Table 4-5: Metal Concentrations Used to Assess Residential Exposures

Medium	Units	Metal Concentrations					
		Antimony	Beryllium	Cadmium	Cobalt	Copper	Nickel
Drinking Water	µg/L	0.97	0.2	0.083	0.04	44	1.3
Ambient Air	µg/m^3	0.0011	0.0001	0.0007	0.002	0.112	0.033
Soil	µg/g	91.1	4.56	35.3	262	2720	17000
Backyard Root Vegetables	µg/g	0.0008	0*	0.049	0.048	1.92	1.82
Backyard Other Vegetables	µg/g	0.021	0.007	0.063	0.083	1.06	1.58

* beryllium was not detected in root vegetables taken from gardens from Rodney Street community

4.3 Metal Exposures in Individual Media

In assessing the total daily intakes of each metal of concern in the Rodney Street community, it is necessary to determine the contribution that each individual exposure pathway makes to the daily total. Each of the potential exposure pathways has been assessed individually for the residents of the Rodney Street community. These individual contributions of each pathway are then combined to provide estimates of the total daily intake of each metal from all sources for each receptor age group (Section 4.4). Exposures from the individual pathways identified in Section 4.1 are summarized in the following sections. Detailed discussions of all pathways are provided in Appendix 3 of the report.

4.3.1 Intake of Metals from Supermarket Foods

Estimates of the daily dietary intakes of metals from supermarket foods are generally limited and the amount of information available varies widely between metals. The metals of concern in Port Colborne include, antimony, beryllium, cadmium, cobalt, copper, and nickel. Information regarding daily dietary intakes of these metals has been taken from regulatory agencies in Canada and internationally. Additional information has been taken from the available literature. For the purposes of assessing likely daily dietary metal intakes for the residents of the Rodney Street community, preference has been given to data generated from the Canadian population. It was felt that information from Canadian sources would provide the best reflection of likely dietary habits and metal

intakes for Rodney Street community residents. The daily dietary intake of metals is discussed in detail in Appendix 4. A summary of the daily dietary intake of metals for all age groups is summarized in Table 4-6. These estimates have been used in conjunction with those from the other media to develop total daily intake values for each metal (Section 4.4).

Table 4-6: Estimated Daily Intakes of Metals from Supermarket Food

Receptor	Daily Intakes of Metals from Supermarket Food (µg/day)					
	Antimony	Beryllium	Cadmium	Cobalt	Copper	Nickel
Infant	1.3	4.8	5.08	4.18	518	180
Toddler	2.3	8.6	10.6	7	822	264
Child	3.5	13.2	16.8	10	1230	329
Teen	4	15	17.3	12	1520	340
Adult	3.4	12.7	14.8	10.5	1430	311

4.3.2 Intake of Metals from Drinking Water

The intake of metals from drinking water depends upon the level of metal in the water and the amount of water consumed by the average person in a day. Residents in the Rodney Street community are supplied with municipal water that is not derived from groundwater, but rather, from Lake Erie. Therefore, water quality monitoring data for the town of Port Colborne was used to estimate the exposures to metals in drinking water for residents of the Rodney Street community. The concentration of each metal in the municipal supply is listed in Table 4-5. These values have been used to estimate the daily intake of antimony, beryllium, cadmium, cobalt, copper and nickel, for each receptor age group considered. The daily intake estimates for each metal for each age group are summarized in Table 4-7. A detailed discussion of the calculations used to estimate the daily intakes is provided in Appendix 3 of the report. The data in Table 4-7 shows that the daily intakes of most metals are generally below 1 µg/day for most metals. The notable exception is copper, where daily intakes for all age groups are greater than 1 µg/day and range between 13.2 and 66 µg/day. The contribution that drinking water makes to total daily exposure is discussed in Section 4.4.

Table 4-7: Estimated Daily Intakes of Metals from Drinking Water

Receptor	Daily Intakes of Metals from Drinking Water (µg/day)					
	Antimony	Beryllium	Cadmium	Cobalt	Copper	Nickel
Infant	0.29	0.06	0.025	0.012	13	0.39
Toddler	0.58	0.12	0.056	0.024	26	0.78
Child	0.78	0.16	0.066	0.032	35	1.0
Teen	0.97	0.2	0.083	0.040	44	1.3
Adult	1.5	0.3	0.12	0.060	66	2.0

4.3.3 Intake of Metals from Ambient Air

The risks associated with inhalation exposures to metals in the Rodney Street community have been assessed in two ways in this report.

Firstly; the potential ingestion exposures associated with inhalation exposures to metal bearing particles is considered. This type of exposure is considered in this section of the report.

Secondly; the potential human health risks directly associated with inhaled metals were assessed by comparing the highest annual average air concentrations in the MOE Port Colborne or Environment Canada air monitoring data for Ontario (Table A3-7, Appendix 3) with the appropriate inhalation exposure limit This latter exposure has been directly assessed in the *Risk Characterization* section of the report (Section 5.0).

In Port Colborne, inhaled metals will be associated with particulate matter and will not be present as free metal. Therefore, there is a potential for the inhaled particulate matter to be cleared from the lungs, through mucocilliary transport, and swallowed. Material cleared from the lungs in this fashion will add to the total daily ingestion of metal. The amount of particulate delivered to the stomach by this process is difficult to predict with any accuracy. Therefore, to provide conservative estimates of the amount of metal ingested as a result of the clearance of inhaled particles, it has been assumed that all inhaled metal is cleared from the lung and passed to the stomach. This approach will over estimate the contribution that inhalation exposures make to the total daily intakes of metals. The highest reported annual average level of each metal (Table 4-5) has been used to estimate the daily ingestion intake of metals following inhalation for people living in the Rodney Street community. The rationale for using annual average ambient air quality monitoring information, and the calculations used to estimate daily intakes of each metal for each age group are discussed in detail in Appendix 3. The data in Table 4-8 shows that inhalation exposures make a very small contribution to ingestion exposures for the metals in soil in the Rodney Street community, even when it has been assumed that all inhaled material is passed to the stomach. Thus, it can be concluded that inhalation exposure to metals does not make a significant contribution to ingestion exposures to metals for the residents of the Rodney Street community. However, these intake estimates have been used in conjunction with the other values to develop total ingestion intake estimates for each metal (Section 4.4).

Table 4-8: Estimated Daily Intakes of Metals from Ambient Air

Receptor	Daily Intakes of Metals from Ambient Air (μg/day)					
	Antimony	Beryllium	Cadmium	Cobalt	Copper	Nickel
Infant	0.0035	0.00038	0.0022	0.0064	0.36	0.11
Toddler	0.016	0.0018	0.01	0.029	1.6	0.48
Child	0.022	0.0024	0.014	0.041	2.6	0.67
Teen	0.025	0.0028	0.016	0.046	2.6	0.76
Adult	0.25	0.0027	0.016	0.046	2.6	0.76

4.3.4 Intake of Metals from Backyard Vegetables

Eating vegetables grown in backyards where metal levels are above typical levels, represents a potential exposure pathway if the metals present in the soil are taken up into the vegetables. The exposures received by people eating such produce depends upon the concentration of the metals in the vegetables and the amount of vegetables consumed from backyard gardens on an annual basis. The current assessment has assumed that backyard garden produce is consumed on a daily basis throughout the year. The amount of backyard garden vegetables consumed on a annually averaged daily basis is discussed in detail in Appendix 6.

As part of the on-going work in Port Colborne, samples of backyard produce have been collected by the MOE and Jacques Whitford Environmental Limited (JWEL) from Rodney and Mitchell Streets. The levels of individual metals in the various types of produce tested are provided in Appendix 1 of this report. For the purposes of this assessment, backyard garden produce has been divided into two general categories;

root vegetables includes; beet root and radish samples from Rodney and Mitchell Street gardens and the Wainfleet bog

other vegetables. includes; beet tops, celery, lettuce, peppers and tomatoes from Rodney and Mitchell Street gardens and the Wainfleet bog

An examination of metal levels in vegetables and the soils in which they were grown showed that a relationship does exist between the levels of metals in vegetables and corresponding soils (Appendix 3). Therefore, metal levels in soil were not used to predict the uptake of metals into vegetable as a means of estimating potential human exposure. Rather, the highest level of each metal reported in both of these categories were used to estimate daily intakes of metals from backyard garden produce. The calculation of daily intakes of metals from backyard produce is discussed in detail in Appendix 3. Summaries of the daily intake estimates for each metal from root and other vegetables, for each age group are shown in Table 4-9 and Table 4-10 respectively.

The intake estimates for root and other vegetables for each metal and each receptor age group, were used in conjunction with intake estimates from the other sources to develop total daily intake estimates for each metal and age group (Section 4.4).

Table 4-9: Estimated Daily Intakes of Metals from Backyard Root Vegetables

Receptor	Daily Intakes of Metals from Backyard Root Vegetables (μg/day)					
	Antimony	Beryllium[1]	Cadmium	Cobalt	Copper	Nickel
Infant	0.065	0	0.4	0.39	16	15
Toddler	0.082	0	0.5	0.49	20	19
Child	0.13	0	0.78	0.76	31	29
Teen	0.18	0	1.1	1.1	43	41
Adult	0.15	0	0.95	0.93	37	35

1: beryllium was not detected in root crops from the Port Colborne area

Table 4-10: Estimated Daily Intakes of Metals from Other Backyard Vegetables

Receptor	Daily Intakes of Metals from Other Backyard Vegetables (µg/day)					
	Antimony	Beryllium	Cadmium	Cobalt	Copper	Nickel
Infant	0.15	0.047	0.45	0.59	7.5	11
Toddler	0.14	0.044	0.42	0.55	7	10
Child	0.2	0.064	0.61	0.8	10	15
Teen	0.25	0.078	0.74	0.98	13	19
Adult	0.3	0.093	0.89	1.2	15	22

4.3.5 Intake of Metals from Soil

The ingestion of soil that contains metal represents a potential exposure pathway for people who live in the homes in the Rodney Street community. The daily intake of metal from soil depends upon the amount of soil ingested and the level of metal bound to soil particles. The soil monitoring program conducted by the MOE in the Rodney Street community showed that metal levels in the soil varied across the community. It also showed that metal levels in soil varied across the sampling horizon of 30 cm. The results of the sampling program are discussed in detail in Part A. A summary of the soil monitoring results is presented in Appendix 1 of this report. Because elevated levels of metals appear to be confined to the top 30 cm of soil, it is possible that typical gardening activities could bring materials to the surface and thereby be available for exposure. Therefore, the highest level of each metal reported in the top 30 cm of soil was used to assess exposure for residents of the Rodney Street community. This approach will provide estimates of reasonable maximum exposures for all receptor age groups.

In addition to the amount of metal ingested with soil, the effective intake of metal is also dependent upon the amount of metal released from the soil during digestion. Only metal that is released from soil into the stomach or intestines during digestion can be considered to be accessible to the body and available for uptake. Any metal not released from soil is excreted in the faeces and does not have the opportunity to cause adverse health effects. Therefore, in assessing exposure and potential human health risks, it is necessary to consider the amount of metal actually released from the soil into the gut and not the amount of metal ingested with the soil, when assessing exposures and the potential for human health effects to occur.

The metals in the soil in the Rodney Street community are generally insoluble in water and tend to remain bound to soil particles under neutral conditions (pH 6 - pH 8). However, the solubility of the metals increases under acidic conditions. Therefore, under the acidic conditions of the stomach, it is reasonable to expect that some metal will be released and be accessible to the body and available for uptake. The amount of metal released from soil from the Rodney Street community has been examined by subjecting the soil to a simulated stomach acid digestion and measuring the amount of each metal released from the soil into the acid solution. These results, expressed as a percentage of the total metal level in the original soil sample have been used to correct the estimates of metal intake from soil ingestion. The stomach acid leach test used to determine the adjustment factors for each metal is discussed in detail in Appendix 5. The equations used to estimate the adjusted metal intake from ingested soil are provided in Appendix 3. The results of this assessment are summarized in Table

4-11. The estimates of daily metal intakes from ingested soil for each receptor age group have been used in conjunction with the intake estimates from other sources to provide total daily intake estimates for each metal (Section 4.4).

4.3.6 Dermal Contact with Metals in Soil

Daily contact with metals through soil present on the skin represent a potential route of exposure. However, the insoluble nature of most metals in soil limits their bio-accessability for uptake into and through the skin. Where data is available, it shows that dermal uptake of metals is low (Paustenbach, 2000). In determining the amount of metal that could be delivered to the skin from soil, a number of conservative assumptions have been used to provide maximum estimates of potential exposure. It was assumed that soil on the skin would remain in place for a full 24 hour period and that bathing would only remove soil from the skin once every 24 hours. In addition, conservative or default assumptions were made regarding the amount of metal that would be released from the soil to the skin. Detailed discussions of the derivation of the dermal uptake coefficient for each metal and the calculation of the dermal contact exposures are presented in Appendix 7. The dermal contact/uptake values calculated in Appendix 7 were assumed to represent intake values for each metal in order to facilitate their comparison with intakes from the other exposure routes. Estimates of dermal contact/intake are summarized in Table 4-12.

Table 4-11: Estimated Daily Intakes of Metals from Soil Ingestion

Receptor	Daily Intakes of Metals from Soil Ingestion (µg/day)					
	Antimony	Beryllium	Cadmium	Cobalt	Copper	Nickel
Infant	0.0062	0.0003	0.0023	0.11	2.1	6.9
Toddler	0.0141	0.00069	0.0054	0.26	4.8	16
Child	0.0141	0.00069	0.0054	0.26	4.8	16
Teen	0.0035	0.00017	0.0013	0.064	1.2	3.9
Adult	0.0035	0.00017	0.0013	0.064	1.2	3.9

Table 4-12: Estimated Daily Intakes of Metals from Dermal Contact

Receptor	Daily Intakes of Metals from Dermal Contact (µg/day)					
	Antimony	Beryllium	Cadmium	Cobalt	Copper	Nickel
Infant	0.38	0.016	0.15	0.23	132	14
Toddler	0.61	0.03	0.23	0.37	209	23
Child	1	0.05	0.39	0.61	347	37
Teen	1.6	0.079	0.61	0.95	545	59
Adult	1.5	0.075	0.58	0.91	521	56

4.4 Estimating Total Daily Intakes Of Metals

In order to estimate the potential health effects associated with exposure to metals for the residents of the Rodney Street community, it is necessary to know the total daily intakes of metals from all sources. In the Rodney Street community, two types of exposures can be considered to occur;

General Exposures:	these can be defined as; *exposures that are common across the Rodney Street community, Port Colborne and the Ontario Population*. These include metal intakes from supermarket food, drinking water and ambient air.
Rodney Street Community Specific Exposures:	these can be defined as; *exposures that are directly affected by the metals present in the soil on the properties in the Rodney Street community*. These include metal intakes from backyard garden produce, ingestion of soil and dermal contact with soil.

Total metal intakes from General and Rodney Street community specific exposures have been assessed separately to provide an indication of any additional exposure burdens that may be experienced by the residents of the Rodney Street community as a result of elevated levels of metals in the community. General and Rodney Street community specific exposures for each metal for all receptor age groups are provided in the following sections. In addition to providing estimates of total daily intakes on a µg/day basis, each of the following sections provided *Estimated Daily Intake* (EDI) values for each receptor group on a per body weight basis, expressed as µg/kg-day. These can be considered as dose estimates and are necessary in the estimation of *chronic daily intakes* (CDI) which are used to estimate life-time averaged daily doses (LADD). The LADD and its use in estimating potential human health risks is discussed in detail in Appendix 2, and is calculated in Section 5 (Risk Characterization).

4.4.1 Total Daily Intakes of Antimony

The contributions that general and Rodney Street community specific exposures make to the total daily intake of antimony are summarized in Table 4-13 and 4-14 respectively. The data shows that supermarket food makes the largest contribution to the total daily intake of antimony for all age groups. It also suggests that dermal contact with antimony will make a significant contribution to daily intakes for all receptors. It should be noted however that the estimates of dermal exposure are based on a very conservative assumption the amount of antimony released from the soil during a 24 hour digest of soil in strong acid would also be released from the soil and be accessible to the skin. As noted in Appendix 7, information relating to the uptake of metals into the skin from soil is extremely limited. Of the six metals considered in this assessment, dermal uptake factors are available for two; cobalt and nickel. For these two metals, the factors used to assess potential dermal exposures were 0.0004 and 0.00038 respectively (Appendix 7). These values are 10-fold lower than the default

factor used to estimate dermal exposures to antimony in soil. If the dermal absorption factor for antimony is similar to that for cobalt and nickel, the contribution that dermal contact makes to the total exposure to antimony would be reduced 10-fold and the dermal contribution to total daily exposure would be comparable to the contribution made by the ingestion of backyard root vegetables (Table 4-14). While it is unlikely that dermal exposure to antimony is a significant contributor to total daily exposure, the absence of antimony specific data on dermal uptake dictates that a conservative approach be used to estimate exposures. The implications of these exposures and the potential for health effects to develop as a result of theses exposures is discussed in Section 5.0.

Table 4-13: Total Daily Intakes of Antimony: General Exposures

Receptor	Intake for Individual Media (µg/day)			Total (µg/day)	Body Weight (kg)	EDI[1] (µg/kg-day)
	Supermarket	Drinking Water	Ambient Air			
Infant	1.3	0.29	0.0035	1.59	8.2	0.19
Toddler	2.3	0.58	0.016	2.90	16.5	0.18
Child	3.5	0.78	0.022	4.30	32.9	0.13
Teen	4	0.97	0.025	5.00	59.7	0.084
Adult	3.4	1.5	0.25	5.11	70.7	0.072

1: EDI = Estimated Daily Intake expressed in µg/kg-day

Table 4-14: Total Daily Intakes of Antimony: Rodney Street Community Specific Exposures

Receptor	Intake for Individual Media (µg/day)				Total (µg/day)	Body Weight (kg)	EDI[1] (µg/kg-day)
	Root Veg	Other Veg	Soil Ingestion	Dermal			
Infant	0.065	0.15	0.0062	0.38	0.60	8.2	0.07
Toddler	0.082	0.14	0.014	0.61	0.85	16.5	0.05
Child	0.13	0.2	0.014	1	1.34	32.9	0.04
Teen	0.18	0.25	0.0035	1.6	2.03	59.7	0.034
Adult	0.15	0.3	0.0035	1.5	1.95	70.7	0.028

1: EDI = Estimated Daily Intake expressed in µg/kg-day

4.4.2 Total Daily Intakes of Beryllium

The contributions that general and Rodney Street community specific exposures make to the total daily intake of beryllium are summarized in Table 4-15 and 4-16 respectively. The data shows that supermarket food and drinking water make the largest contributions to the total daily intakes of beryllium accounting for more than 99.8% of the total daily intake for infants and toddlers. As the consumption of backyard garden vegetables increases across the age groups, the contribution the general exposures make to the total daily intakes falls from 96.8% in children to 95.5% in adults. This suggests that the daily exposures to beryllium experienced by residents in the Rodney Street community of Port Colborne do not differ from those experienced by the general Ontario population. The implications of these exposures and the potential for health effects to develop as a result of theses exposures is discussed in Section 5.0.

Table 4-15: Total Daily Intakes of Beryllium: General Exposures

Receptor	Intake for Individual Media (µg/day)			Total (µg/day)	Body Weight (kg)	EDI[1] (µg/kg-day)
	Supermarket	Drinking Water	Ambient Air			
Infant	4.8	0.06	0.00038	4.86	8.2	0.59
Toddler	8.6	0.12	0.0018	8.72	16.5	0.53
Child	13.2	0.16	0.0024	13.36	32.9	0.41
Teen	15	0.2	0.0028	15.20	59.7	0.25
Adult	12.7	0.3	0.0027	13.00	70.7	0.18

1: EDI = Estimated Daily Intake expressed in µg/kg-day

Table 4-16: Total Daily Intakes of Beryllium: Rodney Street Community Specific Exposures

Receptor	Intake for Individual Media (µg/day)				Total (µg/day)	Body Weight (kg)	EDI[1] (µg/kg-day)
	Root Veg	Other Veg	Soil Ingestion	Dermal			
Infant	0	0.047	0.0003	0.019	0.07	8.2	0.0081
Toddler		0.044	0.00069	0.03	0.07	16.5	0.0045
Child	0	0.064	0.00069	0.05	0.11	32.9	0.0035
Teen	0	0.078	0.00017	0.079	0.16	59.7	0.0026
Adult	0	0.093	0.00017	0.075	0.17	70.7	0.0024

1: EDI = Estimated Daily Intake expressed in µg/kg-day

4.4.3 Total Daily Intakes of Cadmium

The contributions that general and Rodney Street community specific exposures make to the total daily intake of cadmium are summarized in Table 4-17 and 4-18 respectively. The data shows that supermarket food and backyard produce make the largest contributions to total daily intakes for all age groups. The contribution to total daily intakes made by general exposures ranges between 78.5% in infants to 86.8% in children. In teens and adults, general exposures account for 83.2 and 81.7% respectively. This indicates that Rodney Street community specific exposures make a measurable contribution to the total daily exposures to cadmium for residents of the Rodney Street community. The implications of these exposures and the potential for health effects to develop as a result of theses exposures is discussed in Section 5.0

Table 4-17: Total Daily Intakes of Cadmium: General Exposures

Receptor	Intake for Individual Media (µg/day)			Total (µg/day)	Body Weight (kg)	EDI[1] (µg/kg-day)
	Supermarket	Drinking Water	Ambient Air			
Infant	5.08	0.025	0.0022	5.11	8.2	0.62
Toddler	10.6	0.05	0.01	10.66	16.5	0.65
Child	16.8	0.066	0.014	16.88	32.9	0.51
Teen	17.3	0.083	0.016	17.40	59.7	0.29
Adult	14.8	0.12	0.016	14.94	70.7	0.21

1: EDI = Estimated Daily Intake expressed in µg/kg-day

Table 4-18: Total Daily Intakes of Cadmium: Rodney Street Community Specific Exposures

Receptor	Intake for Individual Media (μg/day)				Total (μg/day)	Body Weight (kg)	EDI[1] (μg/kg-day)
	Root Veg	Other Veg	Soil Ingestion	Dermal			
Infant	0.4	0.45	0.0023	0.15	1.00	8.2	0.12
Toddler	0.5	0.42	0.0054	0.23	1.16	16.5	0.070
Child	0.78	0.61	0.0054	0.39	1.79	32.9	0.054
Teen	1.1	0.74	0.0013	0.61	2.45	59.7	0.041
Adult	0.95	0.89	0.0013	0.58	2.42	70.7	0.034

1: EDI = Estimated Daily Intake expressed in μg/kg-day

4.4.4 Total Daily Intakes of Cobalt

The contributions that general and Rodney Street community specific exposures make to the total daily intake of cobalt are summarized in Table 4-19 and 4-20 respectively. The data shows that supermarket food and backyard produce make the largest contributions to total daily intakes for all age groups. The contribution to total daily intakes made by general exposures ranges between 71.0% in infants to 76.5% in toddlers. In teens and adults, general exposures account for 74.4 and 72.6% respectively. The data also shows that exposures to cobalt in drinking water and ambient air are significantly lower that exposures through the other pathways. This indicates that Rodney Street community specific exposures make a measurable contribution to the total daily exposures to cobalt for residents of the Rodney Street community. The implications of these exposures and the potential for health effects to develop as a result of theses exposures is discussed in Section 5.0.

Table 4-19: Total Daily Intakes of Cobalt: General Exposures

Receptor	Intake for Individual Media (μg/day)			Total (μg/day)	Body Weight (kg)	EDI[1] (μg/kg-day)
	Supermarket	Drinking Water	Ambient Air			
Infant	4.18	0.012	0.0064	4.20	8.2	0.51
Toddler	7	0.024	0.029	7.05	16.5	0.43
Child	10	0.032	0.041	10.07	32.9	0.31
Teen	12	0.04	0.046	12.09	59.7	0.20
Adult	10.5	0.06	0.046	10.61	70.7	0.15

1: EDI = Estimated Daily Intake expressed in μg/kg-day

Table 4-20: Total Daily Intakes of Cobalt: Rodney Street Community Specific Exposures

Receptor	Intake for Individual Media (μg/day)				Total (μg/day)	Body Weight (kg)	EDI[1] (μg/kg-day)
	Root Veg	Other Veg	Soil Ingestion	Dermal			
Infant	0.39	0.59	0.11	0.23	1.32	8.2	0.16
Toddler	0.49	0.55	0.26	0.37	1.67	16.5	0.10
Child	0.76	0.8	0.26	0.61	2.43	32.9	0.07
Teen	1.1	0.98	0.064	0.95	3.09	59.7	0.052
Adult	0.93	1.2	0.064	0.91	3.10	70.7	0.044

1: EDI = Estimated Daily Intake expressed in μg/kg-day

4.4.5 Total Daily Intakes of Copper

The contributions that general and Rodney Street community specific exposures make to the total daily intake of copper are summarized in Table 4-21 and 4-22 respectively. The data shows that supermarket food and dermal contact make the largest contributions to total daily intakes for all age groups. The contribution to total daily intakes made by general exposures ranges between 70.8% in teens to 76.6% in toddlers. As noted for antimony (Section 4.4.1), the contribution attributed to dermal exposure is likely to be a substantial over estimate of actual exposures through the skin. However, in the absence of copper-specific dermal uptake coefficient data the factor used in this assessment will provide conservative estimates of exposure for all receptor age groups. The data presented in Tables 4-21 and 4-22 show that Rodney Street community specific exposures make a measurable contribution to the total daily exposures to copper for residents of the Rodney Street community. The implications of these exposures and the potential for health effects to develop as a result of theses exposures is discussed in Section 5.0

Table 4-21: Total Daily Intakes of Copper: General Exposures

Receptor	Intake for Individual Media (µg/day)			Total (µg/day)	Body Weight (kg)	EDI[1] (µg/kg-day)
	Supermarket	Drinking Water	Ambient Air			
Infant	518	13	0.36	531.36	8.2	65
Toddler	822	26	1.6	849.60	16.5	51
Child	1230	35	2.3	1267.30	32.9	39
Teen	1520	44	2.6	1566.60	59.7	26
Adult	1430	66	2.6	1498.60	70.7	21

1: EDI = Estimated Daily Intake expressed in µg/kg-day

Table 4-22: Total Daily Intakes of Copper: Rodney Street Community Specific Exposures

Receptor	Intake for Individual Media (µg/day)				Total (µg/day)	Body Weight (kg)	EDI[1] (µg/kg-day)
	Root Veg	Other Veg	Soil Ingestion	Dermal			
Infant	16	7.5	2.1	132	157.60	8.2	19
Toddler	20	7	4.8	209	240.80	16.5	15
Child	31	10	4.8	347	392.80	32.9	12
Teen	43	13	1.2	545	602.20	59.7	10
Adult	37	15	1.2	521	574.20	70.7	8.1

1: EDI = Estimated Daily Intake expressed in µg/kg-day

4.4.6 Total Daily Intakes of Nickel

The contributions that general and Rodney Street community specific exposures make to the total daily intake of nickel are summarized in Table 4-23 and 4-24 respectively. The data shows that while supermarket food makes the largest single contribution to total daily nickel intakes for all receptor age groups, Rodney Street community specific exposures also make a significant contribution. Unlike the other metals considered in the current assessment where intakes from soil ingestion were relatively small, for nickel, soil ingestion makes a measurable contribution to the total

daily exposure. In comparison to the predicted exposures to nickel from supermarket food, backyard produce, soil ingestion and dermal contact, nickel exposures from drinking water and ambient air are relatively small, accounting for less than 1% of the total daily intakes for al age groups. The data presented in Tables 4-23 and 4-24 show that Rodney Street community specific exposures make a measurable contribution to the total daily exposures to nickel for residents of the Rodney Street community. The implications of these exposures and the potential for health effects to develop as a result of theses exposures is discussed in Section 5.0.

Table 4-23: Total Daily Intakes of Nickel: General Exposures

Receptor	Intake for Individual Media (µg/day)			Total (µg/day)	Body Weight (kg)	EDI[1] (µg/kg-day)
	Supermarket	Drinking Water	Ambient Air			
Infant	180	0.39	0.11	180.50	8.2	22
Toddler	264	0.78	0.48	265.26	16.5	16
Child	329	1	0.67	330.67	32.9	10
Teen	240	1.3	0.76	242.06	59.7	4.1
Adult	311	2	0.76	313.76	70.7	4.4

1: EDI = Estimated Daily Intake expressed in µg/kg-day

Table 4-24: Total Daily Intakes of Nickel: Rodney Street Community Specific Exposures

Receptor	Intake for Individual Media (µg/day)				Total (µg/day)	Body Weight (kg)	EDI[1] (µg/kg-day)
	Root Veg	Other Veg	Soil Ingestion	Dermal			
Infant	15	11	6.9	14	46.90	8.2	5.7
Toddler	19	10	16	23	68.00	16.5	4.1
Child	29	15	16	37	97.00	32.9	2.9
Teen	41	19	3.9	59	122.90	59.7	2.1
Adult	35	22	3.9	56	116.90	70.7	1.7

1: EDI = Estimated Daily Intake expressed in µg/kg-day

5.0 Risk Characterization

The potential health risks for residents of the Rodney Street community were characterized using two procedures:

One, the general and Rodney Street community specific exposures were combined into the total metal intake from all exposure pathways and were compared with the oral exposure limit (RfD, etc.) (Table 3-1) selected for that metal;

Two, potential health risks from inhaling airborne metals were assessed by comparing the highest annual average air concentration in the MOE air monitoring data for Port Colborne or Environment Canada air monitoring data for Ontario (Table A3-7) with the selected inhalation exposure limit (RfC, unit cancer risk, etc.) (Table 3-1 and Table 3-2).

In order to compare the estimated daily exposures to each metal calculated for each of the receptor age groups, it is necessary to convert the individual exposures into a life-time averaged daily dose (LADD). The rationale for using life-time averaged daily doses for estimating the risks associated with life-time exposures is provided in Appendix 2. The LADD is calculated as shown in equation 5-1.

Eq 5-1:

$$LADD = \sum_{1}^{n}\left(\frac{EDI_{1..n} * Time_{1..n}}{70 years}\right)$$

Where:	LADD	= Life-Time Averaged Daily Dose	µg/kg-day
	$EDI_{1..n}$	= Estimated Daily Intake of age group n	µg/kg-day
	$Time_{1..n}$	= Time spent in each age group	years

From equation 5-1 it can be seen that the total LADD is a sum of the fractional LADD contributions made by exposures that occur during each life stage (receptor age groups). For the purposes of this assessment, the fractional LADDs for general and Rodney Street community specific exposures have been calculated for each receptor age group (identified as LADD*f* in the tables). The total LADDs for the general and Rodney Street community specific exposures are also listed to provide an indication of what factors make the greatest contributions to the final LADD. The final LADDs are compared to their respective oral RfD values in making the final estimates of potential risk. LADDs that are lower than their respective RfD values indicate that exposures are below the identified exposure limit and that human health effects would not be expected to occur.

Graphical representations of the EDIs for the individual receptor age groups as well as the LADD compared to the RfD are also provided for the six metals carried through the detailed risk assessment. In comparing the individual EDI values to the RfD values, it should be remembered that the US EPA recommends that this serve only as a screening to tool to indicate potential risk but that they are not to be considered as predictive of potential human health effects. Predictive estimates of

potential risk should only be based on a comparison between the LADD and the R*f*D (US EPA, 1992).

5.1 Antimony

5.1.1 Ingestion Exposure to Antimony

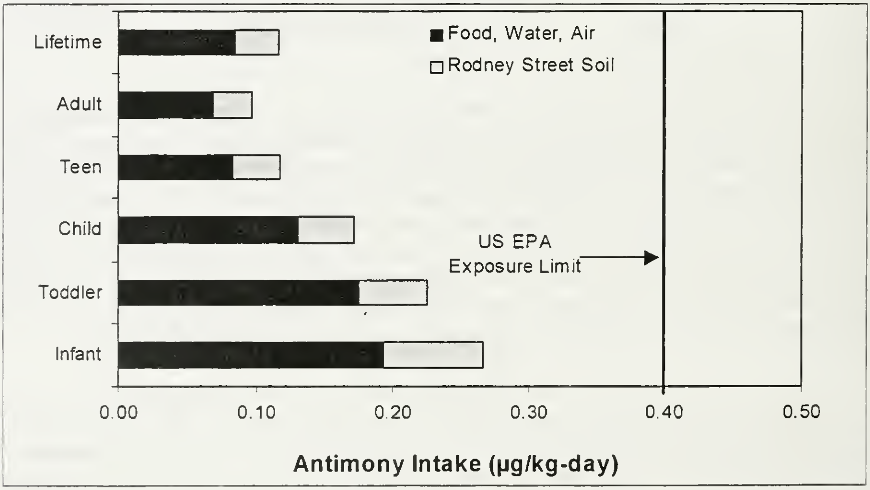
To characterize the potential health risks for residents of the Rodney Street community, the total antimony intake from all exposure pathways (Table 5.1) was compared with the 0.4 µg/kg/day oral exposure limit (US EPA and WHO)(Table 3.1).

Table 5-1: Life-Time Averaged Daily Antimony Intakes for the Rodney Street Community

Metal	Receptor	Years	General Exposures			Rodney St Specific Exposures			Total CDI[4]
			EDI[1]	CDI*f*[2]	Σ CDI[3]	EDI[1]	CDI*f*[2]	Σ CDI[3]	
	0- 6 months	0.5	0.19	0.001		0.070	0.0005		
	7 months -	4.5	0.18	0.011		0.050	0.0032		
Antimony	5 - 11 years	7	0.13	0.013	0.087	0.040	0.0040	0.032	0.12
	12 - 19 years	8	0.08	0.009		0.034	0.0039		
	20 + years	50	0.07	0.051		0.028	0.020		

1: estimated daily intake (µg/kg-day)
2: Chronic Daily Intake Fraction (µg/kg-day)
3: ΣCDI = sum of CDI*f* for General or Rodney Street community specific Exposures (µg/kg-day)
4: Total CDI = Chronic Daily Intake for a life-time exposure to metal in the Rodney Street community (µg/kg-day)

Figure 5-1: General and Rodney Street Community Specific Exposures to Antimony



Inspection of Table 5.1 and Figure 5.1 show that the presence of up to 91.1 µg/g antimony in soil in the Rodney Street community is unlikely to be associated with any adverse health effects. Dietary intake is the predominant contributor to the total daily intake of antimony accounting for between 86% and 96.7% of the total daily intake for residents of the Rodney Street community. Surface soil, through ingestion and dermal absorption accounts for approximately 3% of the total daily intake of antimony. The highest level of antimony reported in subsurface soil in the Rodney Street community was approximately 3.8-fold higher than that reported in surface soil (91.1 µg/g). If subsurface soil was assumed to contribute to daily exposures to antimony in soil, soil would account for about 11% of the total daily exposure (3.8-fold greater than the 3% contribution made by surface soil). Even at these levels the total daily intake for the infant, (receptor with the estimated highest exposure) is approximately 0.25 µg/kg-day which lies well below the RfD of 0.4 µg/kg-day.

5.1.2 Inhalation Exposure for Antimony

Potential health risks from inhaling airborne antimony were assessed by comparing the highest maximum and annual average air concentrations in the Environment Canada air monitoring data for Ontario (Table A3-7, Appendix 3) with the US EPA RfC of 0.2 $\mu g/m^3$ (Table 3.1). In this case, both the maximum antimony concentration (0.012 $\mu g/m^3$) and the highest annual average concentration (0.0011 $\mu g/m^3$) were well below the RfC. Consequently, there appears to be no potential for health related effects from inhalation of antimony.

5.2 Beryllium

5.2.1 Ingestion Exposure to Beryllium

To characterize the potential health risks for residents of the Rodney Street community, the total beryllium intake from all exposure pathways (Table 5-2) was compared with the 2 µg/kg/day oral exposure limit (US EPA)(Table 3.1).

Table 5-2: Life-Time Averaged Daily Beryllium Intakes for the Rodney Street Community

Metal	Receptor	Years	General Exposures			Rodney St Specific Exposures			Total CDI[4]
			EDI[1]	CDIf[2]	Σ CDI[3]	EDI[1]	CDIf[2]	Σ CDI[3]	
Beryllium	0- 6 months	0.5	0.59	0.004	0.24	0.0081	0.0001	0.0027	0.24
	7 months -	4.5	0.53	0.034		0.0045	0.0003		
	5 - 11 years	7	0.41	0.041		0.0035	0.0004		
	12 - 19 years	8	0.25	0.028		0.0026	0.0003		
	20 + years	50	0.18	0.131		0.0024	0.0017		

1: estimated daily intake (µg/kg-day)
2: Chronic Daily Intake Fraction (µg/kg-day)
3: ΣCDI = sum of CDIf for General or Rodney Street community specific Exposures (µg/kg-day)
4: Total CDI = Chronic Daily Intake for a life-time exposure to metal in the Rodney Street community (µg/kg-day)

Inspection of Table 5-2 and Figure 5-2 show that the presence of up to 4.56 µg/g beryllium in soil in the Rodney Street community is unlikely to be associated with any adverse health effects since these conservatively estimated total intakes did not exceed the US EPA *RfD* for any age class. Figure 5-3 shows the estimated daily intakes of beryllium on an expanded scale, to make it easier to see the relative contributions made by general exposures and those received from Rodney Street soil. From Figure 5-3 it can be seen that Rodney Street community specific exposures to beryllium in soil do not make an appreciable contribution to the total daily intakes of beryllium.

Figure 5-2: General and Rodney Street Community Specific Exposures to Beryllium

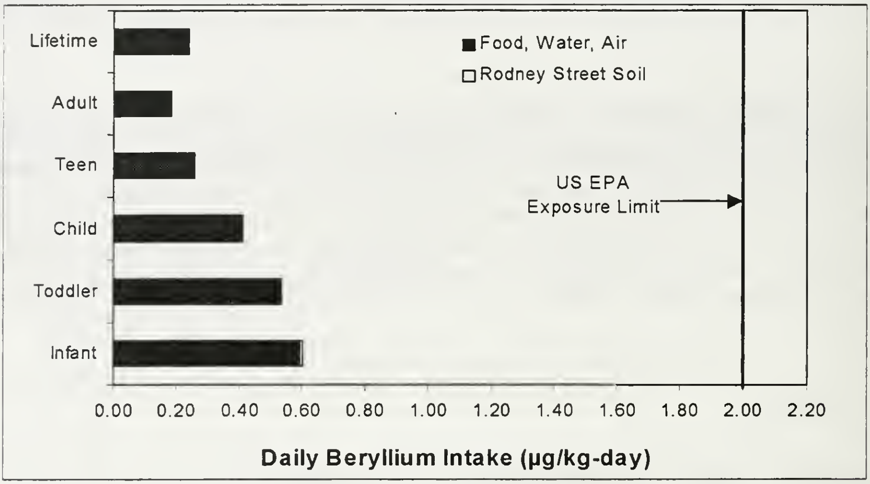
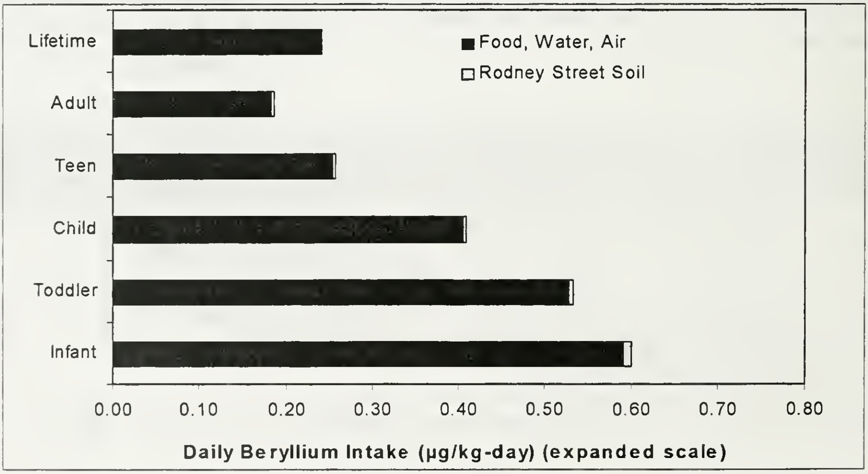


Figure 5-3: Exposures to Beryllium (expanded scale)



5.2.2 Inhalation Exposure to Beryllium

Potential health risks from inhaling airborne beryllium were assessed by comparing the estimated airborne concentration of beryllium in TSP with both the R*f*C of 0.002 $\mu g/m^3$ for non-cancer effects (Table 3.1) and with the US EPA inhalation unit risk of 0.0024 $(\mu g/m^3)^{-1}$ (Table 3.2). In both cases, the estimated airborne beryllium concentration (0.00012 $\mu g/m^3$) in the Rodney Street community (see Appendix 3) is less than the R*f*C and the air concentration at the 10^{-6} lifetime cancer risk level. Consequently, there appears to be no potential for health related effects from inhalation of beryllium.

5.3 Cadmium

5.3.1 Ingestion Exposure to Cadmium

To characterize the potential health risks for residents of the Rodney Street community, the total cadmium intake from all exposure pathways (Table 5-3) was compared with the 1 µg/kg/day oral exposure limit proposed by the US EPA and WHO (Table 3.1). This higher intake limit was used because intakes were estimated for all exposures not just drinking water or diet.

Table 5-3: Life-Time Averaged Daily Cadmium Intakes for the Rodney Street Community

Metal	Receptor	Years	General Exposures			Rodney St Specific Exposures			Total CDI[4]
			EDI[1]	CDI*f*[2]	Σ CDI[3]	EDI[1]	CDI*f*[2]	Σ CDI[3]	
Cadmium	0- 6 months	0.5	0.62	0.004	0.28	0.12	0.0009	0.040	0.32
	7 months -	4.5	0.65	0.041		0.070	0.0045		
	5 - 11 years	7	0.51	0.051		0.054	0.0054		
	12 - 19 years	8	0.29	0.033		0.041	0.0047		
	20 + years	50	0.21	0.15		0.034	0.0243		

1: estimated daily intake (µg/kg-day)
2: Chronic Daily Intake Fraction (µg/kg-day)
3: ΣCDI = sum of CDI*f* for General or Rodney Street community specific Exposures (µg/kg-day)
4: Total CDI = Chronic Daily Intake for a life-time exposure to metal in the Rodney Street community (µg/kg-day)

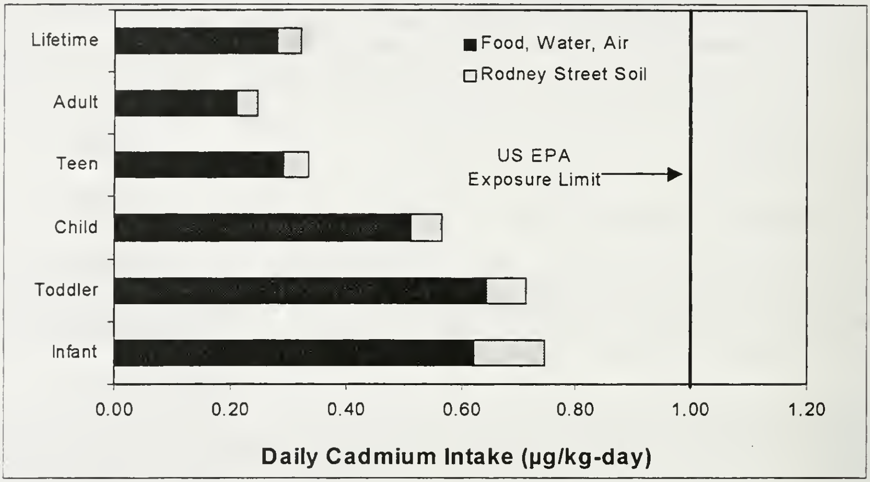
Inspection of Table 5-3 and Figure 5-4 show that the presence of up to 35.3 µg/g cadmium in soil in the Rodney Street community is unlikely to be associated with any adverse health effects since these conservatively estimated total intakes did not exceed the US EPA R*f*D for any age class.

5.3.2 Inhalation Exposure to Cadmium

Potential cancer risks from inhaling airborne cadmium were assessed by comparing the highest annual average air concentration in the Environment Canada air monitoring data for Ontario (Table A3-7) with the US EPA inhalation unit risk (0.0018 $(\mu g/m^3)^{-1}$ (Table 3.2). In this case, the maximum cadmium concentration found in the 1995-1999 Environment Canada monitoring of nine sites spread across Ontario was 0.0067 $\mu g/m^3$, or about 1.1×10^{-5} lifetime risk. Since this is the estimated risk

at the maximum air concentration found and the average air concentration is 0.0007 μg/m^3.or about ten times lower, the overall lifetime cancer from inhalation of cadmium is more likely to be in the 10^{-6} (1-in-a million) to 10^{-5} risk range, a risk range considered negligible by the federal government.

Figure 5-4: General and Rodney Street Community Specific Exposures to Cadmium



5.4 Cobalt

5.4.1 Ingestion Exposure to Cobalt

To characterize the potential health risks for residents of the Rodney Street community, the total cobalt intake from all exposure pathways (Table 5-4) was compared with the 60 μg/kg-day oral exposure limit proposed by the US EPA Region III (Table 3.1).

Table 5-4: Life-Time Averaged Daily Cobalt Intakes for the Rodney Street Community

Metal	Receptor	Years	General Exposures			Rodney St Specific Exposures			Total CDI[4]
			EDI[1]	CDIf[2]	Σ CDI[3]	EDI[1]	CDIf[2]	Σ CDI[3]	
Cobalt	0- 6 months	0.5	0.51	0.003	0.19	0.16	0.0011	0.052	0.24
	7 months -	4.5	0.43	0.027		0.10	0.0064		
	5 - 11 years	7	0.31	0.031		0.070	0.0070		
	12 - 19 years	8	0.20	0.023		0.052	0.0059		
	20 + years	50	0.15	0.11		0.044	0.031		

1: estimated daily intake (μg/kg-day)
2: Chronic Daily Intake Fraction (μg/kg-day)
3: ΣCDI = sum of CDIf for General or Rodney Street community specific Exposures (μg/kg-day)
4: Total CDI = Chronic Daily Intake for a life-time exposure to metal in the Rodney Street community (μg/kg-day)

Inspection of Table 5-4 and Figure 5-5 show that the presence of up to 262 µg/g cobalt in soil in the Rodney Street community is unlikely to be associated with any adverse health effects since these conservatively estimated total intakes did not exceed the US EPA R*f*D for any age class. Figure 5-6 shows the contributions to total daily intakes of cadmium made by general and Rodney Street community specific exposures.

Figure 5-5: General and Rodney Street Community Specific Exposures to Cobalt

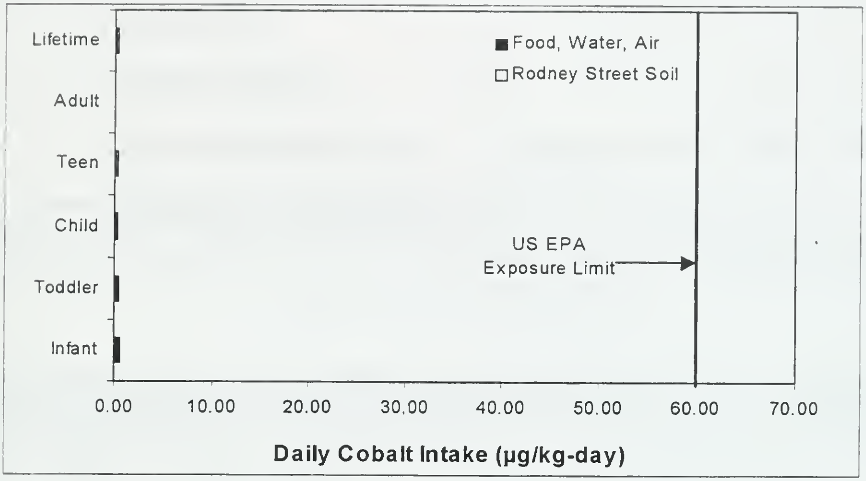
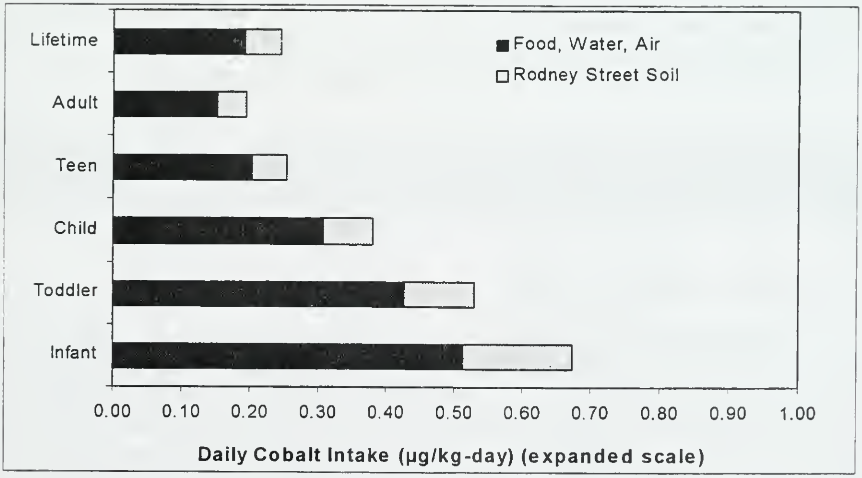


Figure 5-6: Exposures to Cobalt (expanded scale)



5.4.2 Inhalation Exposure to Cobalt

Potential health risks from inhaling airborne cobalt were assessed by comparing the highest annual average air concentration in the Environment Canada air monitoring data for Ontario (Table A3-7) with the US ATSDR inhalation MRL (0.03 $\mu g/m^3$)(Table 3.1). In this case, the maximum cobalt concentration found in the 1995-1999 Environment Canada monitoring of nine sites spread across Ontario (0.017 $\mu g/m^3$) and the highest annual average concentration (0.002 $\mu g/m^3$), are well below this inhalation MRL . Consequently, there appears to be no potential for health related effects from inhalation of cobalt.

5.5 Copper

5.5.1 Ingestion Exposure to Copper

To characterize the potential health risks for residents of the Rodney Street community, the total copper intake from all exposure pathways (Table 5-5) was compared with the Recommended Daily Allowances (RDA) for adults (30 µg/kg-day) or children (50 µg/kg-day) and the tolerable upper intake limit of 140 µg/kg-day proposed by the WHO, 1998 and IOM, 2001 (Table 3.1).

Table 5-5: Life-Time Averaged Daily Copper Intakes for the Rodney Street Community

Metal	Receptor	Years	General Exposures			Rodney St Specific Exposures			Total CDI[4]
			EDI[1]	CDIf[2]	Σ CDI[3]	EDI[1]	CDIf[2]	Σ CDI[3]	
Copper	0- 6 months	0.5	65	0.46	26	19	0.14	9.2	35
	7 months -	4.5	52	3.3		15	0.96		
	5 - 11 years	7	39	3.9		12	1.2		
	12 - 19 years	8	26	3.0		10	1.1		
	20 + years	50	21	15		8.1	5.8		

1: estimated daily intake (µg/kg-day)
2: Chronic Daily Intake Fraction (µg/kg-day)
3: ΣCDI = sum of CDIf for General or Rodney Street community specific Exposures (µg/kg-day)
4: Total CDI = Chronic Daily Intake for a life-time exposure to metal in the Rodney Street community (µg/kg-day)

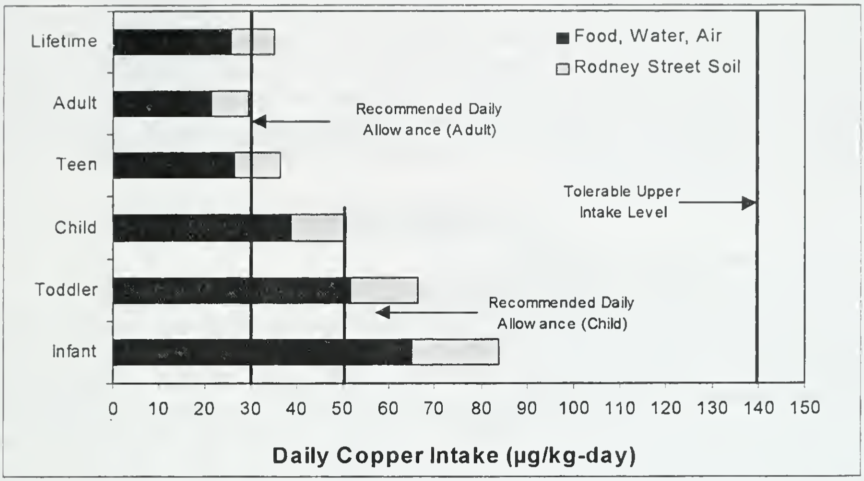
Inspection of Table 5-5 and Figure 5-5 show that the presence of up to 2720 µg/g copper in soil in the Rodney Street community is unlikely to be associated with any adverse health effects since these conservatively estimated total intakes did not exceed the tolerable upper intake limit for any age class.

5.5.2 Inhalation Exposure to Copper

Potential health risks from inhaling airborne copper were assessed by comparing the highest annual average air concentration in the MOE air monitoring data for Port Colborne (Table A3-7) with the chronic air quality criteria for copper used by California (Table 3.1). In this case, the maximum copper concentration found (0.56 $\mu g/m^3$) and the highest annual average concentration (0.112 $\mu g/m^3$), are well below California's chronic inhalation reference exposure limit (REL) (2.4 $\mu g/m^3$)(Table 3.1). Consequently, there appears to be no potential for health related effects from

inhalation of copper.

Figure 5-7: General and Rodney Street Community Specific Exposures to Copper



5.6 Nickel

5.6.1 Ingestion Exposure to Nickel

To characterize the potential health risks for residents of the Rodney Street community, the total nickel intake from all exposure pathways (Table 5-6), was compared with the US EPA RfD of 20 μg/kg/d (Table 3.1). Table 5-6 shows that total nickel intakes are below the RfD for age groups over the age of 5 years. This situation is also true for people in the Rodney Street community even when soil nickel levels are as high as 17,000 μg/g.

Table 5-6: Life-Time Averaged Daily Nickel Intakes for the Rodney Street Community

Metal	Receptor	Years	General Exposures			Rodney St Specific Exposures			Total CDI[4]
			EDI[1]	CDIf[2]	Σ CDI[3]	EDI[1]	CDIf[2]	Σ CDI[3]	
Nickel	0- 6 months	0.5	22	0.16	5.8	5.7	0.041	2.0	7.9
	7 months -	4.5	16	1.0		4.1	0.26		
	5 - 11 years	7	10	1.0		2.9	0.29		
	12 - 19 years	8	4.1	0.46		2.1	0.24		
	20 + years	50	4.4	3.2		1.7	1.2		

1: estimated daily intake (μg/kg-day)
2: Chronic Daily Intake Fraction (μg/kg-day)
3: ΣCDI = sum of CDIf for General or Rodney Street community specific Exposures (μg/kg-day)
4: Total CDI = Chronic Daily Intake for a life-time exposure to metal in the Rodney Street community (μg/kg-day)

For adults exposed to soil containing 17,000 µg/g nickel, their estimated lifetime intake averages 8 µg/kg/d (40% of the US EPA RfD). For the infant age class, total nickel intakes exceed the US EPA RfD by about 25% even in the general population. This is due to a combination of the nickel levels in baby food and the low body weight of infants. This situation exists whatever the soil nickel concentration. For the toddler exposure scenario, the estimated daily intake is 18.5 µg/kg/d at 5000 µg/g and 19.2 µg/kg/d at 10,000 µg/g. A large and fixed percentage of these intake estimates is due to exposures not influenced by soil nickel concentrations (supermarket food, drinking water and ambient air) which form 79% to 82% of the total intake. Even at soil nickel levels of 200 µg/g, the total daily intake is 17.9 µg/kg/day. The relationships of total daily intake, age class and the US EPA RfD are shown in Figure 5-6.

5.6.2 Inhalation Exposure to Nickel

Potential cancer risks from inhaling airborne nickel were assessed by comparing the highest annual average air concentration in the MOE air monitoring data for Port Colborne (Table A3-7, Appendix 3) with the US EPA inhalation unit risk (0.00024 $(\mu g/m^3)^{-1}$ (Table 3.2). In this case, the highest annual average nickel concentration found was 0.033 $\mu g/m^3$, or about 7.8 X 10^{-6} lifetime risk. The US EPA inhalation unit risk was developed for nickel refinery dust which contains a small percentage of nickel oxide (less than 10 %). The airborne nickel inhaled in the Rodney Street community is mainly nickel oxide and does not contain nickel subsulphide, the major carcinogenic component of nickel refinery dusts. While nickel oxide has been classified as a human carcinogen, there are no published or other reliable ways of assessing its carcinogenic potency. There is no evidence to suggest that nickel oxide has a greater carcinogenic potency than nickel refinery dust. Consequently the actual cancer risk for inhaling ambient air in the Rodney Street community is more likely to be below 10^{-6} lifetime risk. This risk range is considered negligible by the federal government.

Figure 5-8: General and Rodney Street Community Specific Exposures to Nickel (17,000 µg/g)

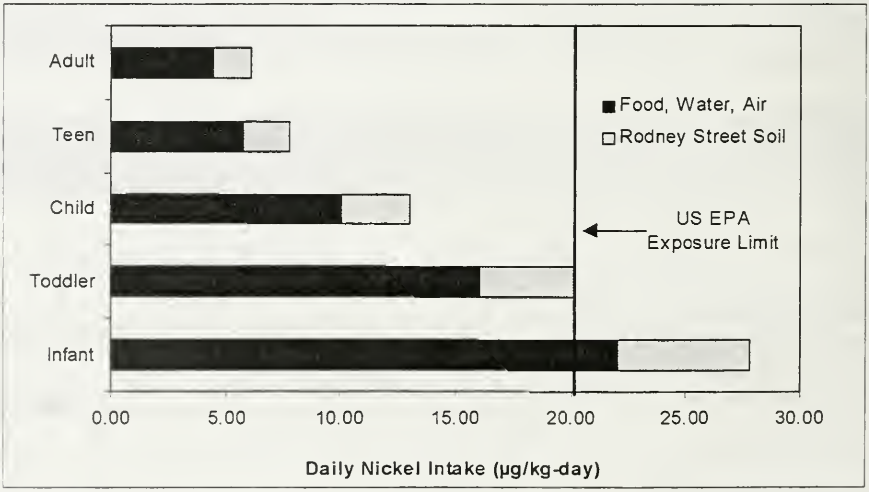
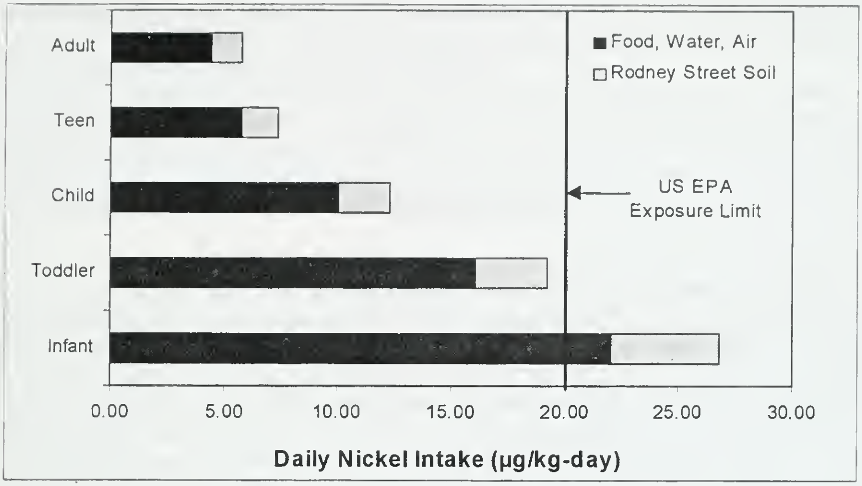


Figure 5-9: General and Rodney Street Community Specific Exposures to Nickel (10,000 µg/g)



5.7 Arsenic

Human Health Significance of Measured Soil Arsenic Levels

Arsenic is a known human carcinogen. Long term chronic ingestion of arsenic has been associated with skin changes including skin cancer and is reported to increase the risk of cancer of the liver, bladder, kidney and lung (ATSDR, 2000). Major public health agencies base their quantitative assessment on skin cancer as the most critical effect. Unlike lead, exposures over the entire lifetime are more important than exposures during childhood only. Because of the extensive experience with risk evaluation of arsenic in soil in other Ontario studies, it is considered that replication of similar calculations would not shed any light of additional value on arsenic levels in this situation. Rather, Port Colborne is compared to these other Ontario communities to determine whether the levels here are out of the ordinary and whether it is plausible that increased health risk could occur.

An important consideration regarding potential exposure to arsenic in these soils is that arsenic ions form insoluble salts with a number of cations in soils and are adsorbed by soil constituents, such as organic colloids and iron and aluminum oxides. Arsenic is held quite strongly by soils, especially fine-textured ones, and is leached very slowly. As such, relatively high levels of arsenic in soil may pose little risk if there are indeed highly insoluble and therefore not available for absorption if swallowed. In fact the measured solubility of arsenic in these soil samples using a simulated stomach acid leach test is very low with a maximum of 1.42 %. This suggests that the arsenic in the Rodney Street community is very tightly bound to soil and has very little potential to cause health effects, even at the highest measured levels in this neighbourhood i.e. 350 µg/g. Consistent with this are the very low and non-detectable levels measured in backyard vegetables

which show that plants are unable to take up the tightly bound arsenic. This also implies that levels many multiples of the MOE arsenic in soil guideline of 20 µg/g (which is based on plant effects, not human health) would not pose undue health risk to residents.

People everywhere, including Ontario, are chronically exposed to low levels of arsenic in the environment and as such everyone has a certain amount of risk. These exposures can occur by a number of different pathways including the normal diet and drinking water. To understand the potential relevance of the measured soil levels in Port Colborne it is useful to compare the levels found with levels elsewhere in the province and in particular with the findings of health studies around arsenic conducted in the province.

The average level of arsenic in the Rodney Street community is approximately 16 µg/g, with the majority of samples lower than 18 µg/g which is the 98th percentile of typical urban parklands in Ontario. Out of all properties sampled there were two which had unusually high arsenic levels (i.e greater than 100 µg/g As in soil). Background soil arsenic levels in North America range from 1 to 40 µg/g. Measured arsenic levels in Port Hope , Ontario average 20 µg/g, with a maximum of around 250 µg/g (MOE, 1990). Most typical urban communities show this type of distribution with a few elevated properties within a given area. These higher levels are sometimes attributable to past herbicide use for weed control. As such there is nothing unusual regarding the soil arsenic levels measured in this community. It is therefore expected that exposure, based on levels alone, would be comparable or perhaps less than other Ontario communities.

In the Port Hope risk assessment study (MOE, 1991)- where average soil levels are roughly double what they are in this case, and had several properties in excess of 100 µg/g - incremental cancer risk levels for soil arsenic exposure were calculated to be less than one-tenth of the calculated cancer risk from arsenic in the normal diet and to be non-significant. As well, the assumed availability of arsenic is soil was 45% for the Port Hope study, whereas in this situation it is maximally 1.4 %. Even if availability is somewhat higher than measured, by corollary, it can be concluded that exposures to the arsenic in soil in Port Colborne would not produce significant cancer risk. Also, it is not anticipated that these levels would lead to increases arsenic levels in people as measured in urine. A study of exposure in a mining village with much higher levels of arsenic in the soil than in Port Colborne showed no relationship between elevated soil arsenic and urinary arsenic in people in all age groups (MOE, 1999)

Although findings in other studies cannot be directly applied to Port Colborne, they do provide a reasonable context for the levels measured in Port Colborne and do suggest that contact with these soils across the range of values measured, is unlikely to result in increases exposures. At the same time, for those few properties where arsenic levels are quite elevated, even though health impacts are not expected, it is desirable to reduce exposure, simply as a matter of precaution as these are unusually elevated above those generally found in the community.

With respect to dermal exposure, dermal absorption of dissolved arsenic compounds may occur, but is considered minimal, and therefore this route of environmental exposure would be considered inconsequential, as skin is rather impermeable to water and dissolved ions (Scheupler and Blackwell, 1971)

The very low levels of arsenic in backyard vegetables suggest no undue exposures would occur through this route. However because arsenic is a carcinogen it is prudent to minimize exposure and as such vegetables should be washed thoroughly before cooking and consumption because soil particles may adhere to leafy vegetables in particular.

5.8 Lead

Human Health Significance of Measured Soil Lead Levels

Lead in soil has long been recognized as posing potential risk, particularly to younger children ages one to four years, who may play in these areas. Because of their higher contact rates with soil and higher rates of intestinal absorption for lead as compared with adults, young children will generally have greater exposures by this pathway. Although exposures of women of child-bearing age due to fetal exposure issues merit consideration, such exposures will generally be much smaller and result in smaller absorbed intakes than for children. Therefore, young children may be considered the most susceptible receptor for exposures for direct soil/dust ingestion, and therefore characterization of risk should focus on this subgroup. Exposure to lead in soil occurs predominantly through the eating of soil or dust. Breathing of dust and skin absorption are considered trivial.

It is useful to compare the reported levels of lead in soil in this neighbourhood with those in other Ontario urban areas in order to postulate whether exposures to lead here could be greater. Bearing in mind that there is no "typical" urban residential site, one may examine other Ontario residential sites in built-up areas that are not obviously associated with any lead-related industry (although the areas may have been influenced to some degree by other industry, vehicle exhaust deposition, etc.). Linzon (1976) reports in a survey of an Ontario downtown area, serving as control for samples collected near a lead industry, lead levels in surface soils (0-5 cm), averaging 482 μg/g with a range of 18 to 1,450 μg/g. Similar ranges of levels are reported in the scientific rationale for the MOE's lead in soil guideline (MOE, 1995). Also, lead levels near roadways and major intersections can easily exceed 500 μg/g (Rinne, 1986). It can thus be suggested that reported on average soil lead levels in the Port Colborne area (mean and median of 222 and 179 μg/g respectively in surface samples) are essentially no greater than, and in many cases less than, those expected for other urban residential sites in Ontario. As well, the pattern of lead levels on these residences is consistent with very localized spots of higher (i.e. > 1,000 μg/g) contamination related to leaded paint or fuel use. By corollary, estimated exposures (and hence blood lead levels) would be predicted to be on average similar to those for other urban Ontario populations.

Another consideration in this situation is the measurement of lead solubility in the Port Colborne soils. Results of tests conducted by the MOE laboratories on several samples indicated a maximum solubility of approximately 5% . In other words, only 5% of the lead in the soil will leach from the soil particles under acidic stomach conditions and be available for absorption into the body and the rest would pass through in stool. Furthermore, in the derivation of the current MOE guideline of 200 μg/g for residential sites (a level to clean up to), relationships between lead intake in water and baby formula were utilized. Lead in drinking water and formula will be essentially entirely soluble and hence, largely bioavailable. Therefore in assessing the potential impact of intake from soils, adjustment must be made for the vast difference in solubility of lead adsorbed to soils versus lead in

drinking water. Even if the solubility of lead in Port Colborne soils were twice the measured maximum (i.e 10%) levels as high as 5X the MOE guideline or more could be without concern as actual uptake of the lead into the body would be very limited..

It is also relevant to discuss briefly the current scientific information relating to lead in soil and blood lead level in young children (for review see MOE, 1995; Davies, 1998; Stern, 1994). This question has been examined to some extent in a number of epidemiological investigations. Some studies have found positive correlations between soil lead and blood lead levels in children, particularly where soil lead levels exceed 1,000 ppm. Blood lead appears to vary directly with soil lead concentrations in some cases. The range of reported average slope factors (which attempt to describe this relationship numerically) is 0.6-8.0 μg/dL per 1,000 μg/g soil lead (MOE, 1995; Davies, 1998) based on roughly 20 studies using a range of data analysis methods. For example, the study of Baltrop et al. (1975) in Derbyshire, England, concluded that soil lead contributed 0.6 (μg/dL)/(mg Pb/g) soil in a rural area where industrial point sources of lead no longer operate. Another study has demonstrated no apparent elevation in mean blood lead concentrations (compared to low exposure groups) for children in two English villages with mean soil lead levels of greater than 1,000 μg/g (Baltrop and Strehlow, 1988). In a more recent review of blood lead studies in mining areas (Steele et al., 1990) with mine waste but no recent or current history of smelting, it is noted that blood leads appear in general not to be elevated despite some very high soil lead concentrations. Average blood lead levels were lower than expected when compared with studies of urban communities or communities with operational smelters.

It is important to realize that environmental conditions greatly influence this relationship, and generally those that exhibit slope factors at the upper end of the range typically involve settings which are arid and lacking grass cover, where the soil lead will be virtually present as lead dust. These sites generally involve operating lead-based industry emissions (lead smelters, mining and battery plants). In contrast, those with the lowest slopes tend to not involve lead dusts or arid conditions. For example, in Baltrop's (1975) study in Derbyshire, almost all soil was grass-covered and there appeared to be little influence of the soil lead upon children's blood lead levels. Although one can not rely on this pattern entirely, it would suggest that in the Rodney Street community where there is not a great deal of bare soil in sampled areas nor a lead-based industry, that a large influence on blood lead by soil lead would not be expected to be at work. For illustrative purposes only, assuming that a very high slope factor operated in this situation, say a 7- 8 μg/dL increase per 1,000μg/g lead in soil, and knowing that background blood lead levels in Ontario children are on average 2 μg/dL, it would require soil lead levels of 1,000 μg/g or greater to cause blood lead levels to increase to the level of concern of 10μg/dL recommended by the US Centre for Disease Control (1990), Health Canada (1996) and the National Academy of Science. From this perspective it can be concluded that based on a highly conservative assumption, soil levels below 1,000 μg/g should not pose an appreciable risk, whereas those at 1,000 μg/g and greater, allowing for some individual variability between different children, may pose a significant risk.

Lead may be taken up into edible plants from the soil; therefore home gardening may also contribute to exposure if the produce is grown in soil containing high lead concentrations. Simple measures such as thorough washing of vegetables prior to preparation and consumption can minimize this type of exposure. Other measures to reduce personal lead exposure are contained in the MOE's Lead in the Environment Fact sheet.

In general based upon consideration of; a) typical urban lead levels in Ontario; b) the very low solubility of lead in these soils; and, c) consideration of findings regarding the observed relationship between soil lead and blood lead in other communities, it can be concluded that exposure to lead in these soils should not result in undue health effects in this community. It cannot be concluded that the reported values on average would lead to undue elevation of blood lead levels overall in this community. At the same time, based upon findings in the literature it is prudent to conclude that in the few residences with reported levels above 1,000 µg/g in soil, there may be some possibility for exposures that result in some elevation in blood lead levels in children who routinely play in these areas.

Consideration of Exposure Reduction and Intervention Levels of Lead in Soil

Individuals can very greatly reduce their exposure to lead in soil in many ways. Regular hand and face washing to remove lead dust from young children, especially before meals, can lower the possibility of accidentally swallowing lead in dust while eating. Regularly cleaning the home of tracked in soil and removal of shoes after having been in soil areas will also reduce exposure. Planting of grass, or other coverings, over bare areas of a yard can lower contact that children and pets may have with soil and the tracking of soil into homes.

With respect to identifying a specific soil lead level which requires intervention through soil removal or other form of remediation, it must be remembered that a large variety of risk factors influence lead exposure in any given situation and as such there is not one universal lead in soil standard that can be applied to all cases. Determining the specific contribution of any particular environmental variable like soil/dust to blood lead level is extremely difficult. This difficulty is also confounded by significant other factors such as socioeconomic status and dietary exposure. For instance, the numerous variables studied in Ontario blood lead studies (MOH, 1984; MOH/MOE, 1990) were unable to account for more than 30% of the variations seen in blood levels in children. The range of observations on the relationship between soil lead and blood lead seen in various studies is a further reflection of the difficulties of determining such associations. As such selection of a single value for this situation involves considerable judgement.

An intervention level or other exposure reduction controls should have some reasonably clear potential for elevating blood lead levels in children to medical levels of concern (10µg/dL blood lead). The range of slope factors relating soil lead to blood lead is quite wide but consideration of the upper end of the range suggests that levels of 1,000 µg/g could result in elevation of blood lead, possibly to levels of concern. Although the low lead solubility of the soils in this community suggest that levels as high as 1,000 µg/g or more are likely to be of no concern from a health point of view, it would seem prudent to err on the side of caution and select 1,000 µg/g as an intervention level for remediation/control at a residence in the absence of individual blood lead testing data for the 9 residences which fall into this category. This would be applied to both bare and grass-covered soils.

Another approach to development of a soil lead level of concern is to utilize multi-pathway exposure modelling. One such tool is the US EPA Integrated Uptake Biokinetic (IUBK) Model for Lead. In simple terms, this model converts estimates of lead exposure from different routes and predicts a blood lead level in children. Utilizing dietary, air , and drinking water intakes and exposure factors for Ontario populations of young children (0.5-4years)(MOE, 1994a) and assuming

conservative soil lead bioavailability of 30%, the model predicted a soil lead concentration of 1700 µg/g associated with a blood lead level of 10 µg/dL. Predicted blood lead levels ranged from 5.5 - 7.7 µg/dL over the soil lead range of 400 - 1,000 µg/g. This is consistent with the analysis above that suggests an intervention level of 1,000 µg/g as sufficiently protective under typical exposure conditions.

Also very relevant to the choice of an appropriate intervention level are existing regulatory standards or guidelines from other jurisdictions. Most recently US EPA (2001) has developed a new lead in soil hazard standard under section 403 of the Toxic Substances Control Act. After initial consideration of a 2,000 µg/g standard and extensive public comment, the following standards were established: a soil lead hazard standard of 400 µg/g for bare soil in play areas and an average of 1200 µg/g for bare soil in non-play areas of the yard. The EPA view is that this is a pragmatic approach which focuses exposure reduction actions on those areas where exposures may be highest for children. This approach would appear reasonable and adoption of a similar stratified approach for this situation seems sensible. Use of a 400 µg/g soil lead level in bare soil of children's play area is prudent given the possibility of higher exposures in these areas for some children.

One other important consideration is that soil removal cannot be guaranteed to reduce actual exposure. In a comprehensive study of the effect of soil replacement on blood lead in children in the South Riverdale community of Toronto, findings could not support a beneficial effect of replacement on children living in homes that had received abatement or partial abatement (Langlois et al., 1996). In fact, 25 children who had soil replaced had a geometric mean blood lead 2.57 µg/dL <u>higher</u> than children that had not had soil replaced. The no abatement group also had blood lead declines over time significantly faster than the abated group. Although abatement activities may have contributed to the worse result in individuals in the abatement group, selection bias and re-contamination are likely more significant factors. Also of note is that in other studies, e.g the Boston lead abatement project (US EPA, 1986), it is often observed that a notably elevated starting soil lead concentration (i.e. in excess of 1,000 to 2,000 µg/g lead in soil) is possibly necessary to see a measurable, significant decline in blood lead. Therefore, those considering soil removal and replacement should bear in mind that the exposure reduction is unlikely to be demonstrable in sites with less than 1,000 µg/g lead in soil, but rather only theoretically reduced. And, in certain cases, blood lead level may be increased following soil removal.

6.0 Discussion of Uncertainties

6.1 General Discussion of Uncertainty

The risk assessment process requires that many assumptions be made, either because of gaps in available monitoring data, or because of an improper or incomplete understanding of how people are likely to be exposed to the contaminants of concern. For example; when estimating daily exposures to a chemical, it is necessary to assume specific body weights in order to determine daily doses on a per body-weight basis, which is necessary in order to make predictive estimates of potential health effects. However, large variations in body weights are normal between people in any of the age groups considered. The use of such assumptions results in a degree of uncertainty in the overall estimates of exposure and risk and in the final conclusions of the risk assessment. As regulators, conservative or precautionary assumptions are made to err on the side of caution and to ensure that the risk assessment does not under estimate the potential for adverse effects.

Another way of approaching uncertainty is to say "how reliable" are the conclusions of the risk assessment, or, what is the "confidence rating" in the process? It is useful to distinguish between at least two types of uncertainty;

Variability In the Data:

This is the most common type of uncertainty. The extent of this type of uncertainty can be quantified statistically. For example, the analytical results for the testing of air, water, soil, and backyard produce from Port Colborne and the Rodney Street community have some degree of sampling and analytical error.

Scientific Judgement:

This type of uncertainty is introduced into the process when scientific judgement must be used to bridge gaps in analytical, toxicological or receptor characteristic data. For example, in estimating dermal exposure to metals it is necessary to use scientific judgement in selecting reasonable dermal uptake factors for metals where direct information is not available. In this type of situation, uncertainty in the parameter may be mitigated either by obtaining more data or by the use of conservative estimates that are applied in a consistent manner throughout the risk assessment.

Several areas of uncertainty exist within the current risk assessment. These are discussed in the following sections. In addition, a discussion of the implications that each has on the overall conclusions of the risk assessment is provided as a summary.

6.2 Uncertainties in Environmental Media Concentrations

There are several areas in the estimates of metal concentrations in environmental media (air, water, soil, backyard vegetables, diet) where uncertainties could have been introduced into the risk assessment including;

Estimates of Dietary Intakes of Metals:

Information on the levels of metals in typical foods and the daily intake of metals from the diet is limited. Reasonable data is available for nickel and several of the other metals considered in this report. However, even within these data sets there are discrepancies in the estimates of daily dietary intakes between the populations examined. For instance, estimates of daily dietary intakes of nickel by the Canadian population are two to three times the levels estimated for the US population (Appendix 4).

The Canadian data was used in this assessment because it was felt that this provided the best reflection of likely dietary intakes for the residents of the Rodney Street community. This approach avoids under estimates of the likely dietary intake of nickel for the residents of the Rodney Street community, which in turn, ensures that maximal estimates of total daily intakes are calculated. Similar approaches are used for the other metals considered in the detailed assessment of risk.

Metal Levels in Backyard Garden Vegetables:

The current assessment has had the benefit of more metal in backyard garden produce information than the previous assessment carried out for Port Colborne (MOE, 1998). However, even the current data only provides limited information on metal levels in a limited selection of crops. To address any uncertainties that may be introduced due to the limited nature of the present data, the metal levels in the examined crops were assumed to be representative of the levels of the levels found in all crops of an equivalent type. In addition, the highest reported level found in the root and other vegetable categories were used to estimate exposures. This approach will over estimate likely intakes of metals.

Metal Levels in Ambient Air:

Ambient air monitoring specific to Port Colborne was available for copper, lead and nickel. The remainder of the metal levels relied on Environment Canada data for southern Ontario. While there is no reason to believe that southern Ontario data for these other metals is not representative of ambient air levels in Port Colborne, the lack of direct data introduces a limited level of uncertainty into the assessment. However, the detailed exposure assessment clearly showed that inhalation exposures to metals in ambient air make a very minor contribution to the total daily exposure and do not, in themselves, represent a risk.

Metal Levels in Soil:

An extensive sampling program was undertaken in the Rodney Street community. Metal levels were assessed in over 1300 samples. However, even with a large data set there is a potential for an error of up to 20% in the reported metal level for any one sample. To address this, the highest level of each metal was used to assess exposures for all residents of the Rodney Street community regardless of where they resided.

Metal Levels in Indoor Dust:

Metal levels were not determined in indoor dust. It was assumed that the daily intake

of soil and dust would occur from the soil with the highest reported level of each metal. It was further assumed that this would occur every day of the year even when winter conditions prevent direct exposure to residential soils. In most cases metal levels in household dust are lower than those reported in soil from the yard. By assuming that all soil and dust ingested comes from the area of highest metal levels yearly exposures to metals through soil and dust ingestion will have been over estimated.

Estimates of Metal Bio-accessibility from Soil:

The metals in the soil, particularly nickel, are largely present in insoluble forms that are tightly bound to the soil matrix. Therefore their accessibility to the body, either in the gut, or through the skin, will depend upon their release from the soil. While the metals are insoluble in water at neutral pH (6.0 - 8.0), their solubility increases under acidic conditions. To address the potential for metal release from the soil during digestion, soils were subjected to a simulated stomach acid leach test (Appendix 5). The digests were conducted over a 24 hour period which is longer than the time material spends in the stomach. The amount of each metal released under these conditions was used to adjust the soil intake estimates to provide an indication of the level of material available for uptake. This approach provides maximum estimates of the amount of each metal available for uptake and consequently will provide maximal estimates of exposure and risk.

6.3 Uncertainties in Receptor Characteristics

There are several areas related to the characteristics and activity patterns of the residents where uncertainties can be introduced into the assessment of exposure and risk.

Receptor Characteristics:

As noted above, the use of single point values to characterize the population does not account for the wide variation that exists within any community. The receptor parameters used in this assessment have been taken from Canadian sources and are based on statistical surveys of the Canadian population. As such they can be considered to be reasonable representative of the residents of the Rodney Street community.

Statistical methods exist to address these variations and provide ranges of exposures and risk for a community. However, these techniques are really only beneficial when an initial worst case assessment demonstrates that potential risks exist. The current assessment made use of conservative assumptions to provide reasonable worst case estimates of exposure and risk. These showed that even at the highest predicted exposures for antimony, beryllium, cadmium, cobalt and cooper, risks do not exist within the community. Therefore a refinement of exposure estimates to account for variation within the population was not deemed necessary.

Activity Patterns:

The current assessment assumed that a person would be living in the Rodney Street community every day of a full 70 year life-time. All exposures were assumed to occur within this community. No correction was made for time spent away for this area. This approach will over estimate all potential exposures.

Dermal Contact with Soil:

Dermal contact for metals is generally considered to be a very minimal pathway of exposure. However, in the current assessment, dermal exposure was estimated to make a reasonable contribution to the total daily exposure for many of the metals examined. This is due to the use of a series of very conservative assumptions regarding the amount of material that may adhere to the skin and the amount of metal that could be released from the soil during contact with the skin. The current assessment used the acid leach test data to represent the amount of metal that would be available for uptake through the skin. This assumption will have over estimated exposure because the level of metal likely to be released from soil under neutral pH condition will be significantly lower. However, in the absence of data to indicate the levels of metals that could reasonably be expected to be released, the acid leach test numbers were used as a worst case.

Consumption of Home Grown Produce:

There is some uncertainty associated with the actual amount of home grown produce a family could consume. For the current assessment, it was conservatively assumed that a family of four would consume 100% of the total garden yield. In addition to this assumption, annual backyard garden yields were based on an assumed garden size and an estimated average crop yield. Depending on the actual family size, garden size, and crop yield, this may be an over- or underestimate of individual exposure. However, given that there was no reduction of exposures to home garden produce due to crop loss (*e.g.*, browsing by wildlife and birds or spoilage), it is concluded that the estimates employed in this assessment would be conservative.

6.4 Uncertainties in Toxicity Information

Each of the toxicologically based exposure limits used to estimate potential health risks have uncertainty factors associated with them. These factors account for the strength of the toxicological data and incorporate uncertainty factors to account for intraspecies and interspecies extrapolations of toxicological data. These uncertainty factors reflect the adequacy of the toxicological data available for each compound. Where toxicological data is poor or limited to one or two studies, large uncertainty factors are applied to insure adequate protection of sensitive members of the population. The result is a general overestimation of potential risks from exposure. Thus, exposures which exceed the exposure limits may not always result in adverse health effects. The uncertainty factor attached to each exposure estimate gives a measure of this potential. The lower the uncertainty factor, the more certain the data and the more predictive of adverse health effects an exposure limit is. In these cases, the probability that exceedances of exposure limits will result in adverse health effects is higher. For exposure limits with higher uncertainty factors, the probability of adverse effects occurring as a result of limited exceedance of exposure limits is thought to decline.

The toxicity and exposure limits selected in this study also have conservative assumptions incorporated into them. However, since these parts of the risk assessment were taken from the reviewed literature and from recognized regulatory agencies, discussion of their uncertainty is beyond the scope of this report. However, it should be noted that the toxicological basis of exposure limits is updated as new information becomes available so every effort was made to ensure that recent information was used.

6.5 Uncertainties in the Risk characterization

Using an Exposure Limit for Nickel Soluble Salts:

In estimating potential risks associated with ingestion and dermal exposures to nickel, the report made use of the non-cancer oral exposure limit for nickel soluble salts put forward by the US EPA. The nickel in soil in the Rodney Street community and Port Colborne has been identified as nickel oxide which is insoluble in water. Therefore there are some potential uncertainties associated with using an oral exposure limit set for a soluble form of the metal. However, the risk assessment made use of a stomach acid leach test to determine the amount of nickel that could be released from the soil matrix during digestion. This digestion would, in fact convert nickel oxide to soluble forms. Once released from the soil matrix, the nickel would be in the form of a soluble salt. Thus, the comparison of this to a exposure limit set for a soluble form of nickel is appropriate.

Use of Life-Time Averaged Daily Doses:

The current assessment developed life-time average daily dose estimates from all age groups (life stages) to estimate the life-time exposure. These values were compared to the reference dose limits set by the US EPA. While not standard practice in risk assessment, it is the approach recommended by the US EPA. The use of a life-time average daily dose is appropriate for the current assessment because exposures have been considered to occur every day over a 70 year life-time, a truly life-time exposure. This approach limits the uncertainty in the assessment to the uncertainties inherent in the reference dose itself.

Estimates of exposure for individual age groups have also been compared to the reference dose, but this serves only as a tool for comparison to determine if potential risks exist. If exposures for individual age groups do not exceed the reference dose then the likelihood that life-time exposures will result in adverse effects is limited. It should be noted that this does not apply to one-time exposures to metals at levels that could result in acutely toxic effects.

6.6 Implications of Uncertainties

Systemic Health Effects:

There are a number of areas where uncertainties may have been introduced into the current assessment of exposure and risk. Throughout, conservative assumptions have been used in an effort to provide estimates of the maximum likely exposures. The objective was to determine if these exposures had the potential to cause adverse health effects in the residents of the Rodney Street community. The risk characterization has shown that even under the conservative conditions that have been assumed to exist in the Rodney Street community, exposures to metals in the soil in the community would not be expected to result in adverse health effects. In most cases, the estimated exposures were significantly lower than the exposure limits identified for each metal.

Contact Dermatitis:

The current assessment for nickel shows that the risks of systemic effects occurring as a result of exposure to nickel in the soil are limited. However, the potential for contact dermatitis to occur in response to skin contact with soil, or through the ingestion of nickel bearing soil in individuals who have already been sensitized to nickel has not been addressed. In the absence of exposure limits set to protect against this effect, the risk assessment process employed here cannot effectively address this issue.

7.0 Recommendations and Conclusions

A plausible worst case exposure estimate was modeled using the maximum reported metal levels in surface soil (0-30 cm) within the Rodney Street community, in municipal drinking water, in backyard produce from the Rodney Street community, in supermarket food and in air monitoring data for Port Colborne or for nine other sites in Ontario. The exposure assessment looked at receptors for each age class (infant, toddler, child, teen and adult) and modeled exposures for inhalation, ingestion and dermal contact using standard exposure assessment methodologies. Adjustments were made for the fact that the predominant form of nickel in the Rodney Street community is insoluble nickel oxide. Acid leachate tests were used to adjust for the amount of each metal that would be bio-accessible in the digestive tract and at the surface of the skin. In other cases, accepted dermal exposure factors were taken from the scientific literature.

Metal exposures for residents of the Rodney Street community were divided into two main components, those related either to dermal contact with metals in the soil or the ingestion of soil and/or backyard garden produce from the Rodney Street community and, general exposures to metals such as those experienced by people elsewhere in Ontario. These general exposures include supermarket food, municipal drinking water and ambient air. The major contributor, in all cases, to total daily intakes of metals is supermarket food which is independent of any local soil metal exposures experienced in the Rodney Street community.

When total metal exposures are broken down by age group, the highest exposures are for the infant and toddler age classes (up to 5 years old). Worst case exposures for these age classes only exceeded the US EPA RfD for nickel.

Potential health risks from inhaling airborne metals were assessed by comparing the highest annual average air concentration in the MOE air monitoring data for Port Colborne or Environment Canada air monitoring data for Ontario (Table A3-7) with the selected inhalation exposure limit (RfC, unit cancer risk, etc.). In all cases except nickel, there appears to be no potential for health related effects from inhalation of these metals in ambient air in the Rodney Street community.

Exposures to lead and arsenic were assessed by comparison with health studies of other Ontario communities with elevated soil concentrations of these metals that were generally higher than those in the Rodney Street community. Conclusions and recommendations for arsenic and lead are described in separate sections below.

7.1 Nickel

For infants, the total nickel intake is mainly due to supermarket food exposure (mainly baby foods). At the maximum soil nickel concentration in the Rodney Street community (17,000 µg/g), the toddler receptor is at the RfD level of exposure. The general exposure component of the toddler's exposure is below the RfD, consequently, reducing its soil exposure by reducing the soil nickel level to 10,000 µg/g reduces the Rodney Street community specific exposure component of the toddler's exposure and reduces its total intake to below the RfD. This adds a small margin of safety. The effect of adjusting the soil nickel level on the size of the Rodney Street community specific exposure

component was calculated using the spreadsheet developed for the exposure assessment. Skin contact with soil in an important contributor to the exposures experienced by toddlers in the Rodney Street community. This estimate is based on conservative assumptions about dermal exposure to nickel sulphate which is more soluble than nickel oxide. Unfortunately, there is no information on dermal exposure to nickel oxide.

In the case of inhaled nickel, the estimated lifetime cancer risk was greater than 1-in-1,000,000. However, this risk estimate was based on an unit inhalation risk factor developed for nickel refinery dusts which contain less than 10 % of nickel oxide (the main form of nickel in soil in the Rodney Street community). While nickel oxide has been classified as a human carcinogen, there are no published or other reliable ways of assessing its carcinogenic potency. There is no evidence to suggest that nickel oxide has a greater carcinogenic potency than nickel refinery dust. Consequently the actual cancer risk for inhaling ambient air in the Rodney Street community is more likely to be below 10^{-6} lifetime risk. This risk range is considered negligible by the federal government.

A site-specific soil intervention level of 10,000 µg nickel/g soil was developed specifically for the Rodney Street community based on toddler exposure. While conservatively estimated, there are several reasons to support the use of this site-specific soil intervention level of 10,000 µg nickel/g. These reasons include:

- uncertainty in the sampling and analytical measurement of nickel in soil
- uncertainty in the estimates of the actual amounts of nickel that would be absorbed into the toddler due to ingestion of, and, dermal contact with soil containing nickel at this concentration
- there may be some uncertainty as to whether the current US EPA RfD of 20 µg nickel / kg - day completely protects against the contact dermatitis experienced by a percentage of the population, mainly female, who are already sensitized to nickel through wearing jewellery, dental or surgical prostheses or other contact with metallic nickel and stainless steel.

7.1.1 Recommendations for Nickel

1. The site-specific soil intervention level of 10,000 µg nickel/g for noncancer effects based on toddler exposure developed specifically for the Rodney Street community, be used to facilitate remediation of affected properties in the Rodney Street community.

7.2 Arsenic

It is concluded that the measured levels of arsenic in these soils do not pose an undue health risk to residents of this community based upon consideration of:

1.) comparison to typical levels elsewhere;
2.) knowledge of outcomes of health studies involving arsenic in soil exposure in other Ontario communities and;
3.) the very low measured availability of the arsenic in these soils.

Measured levels of arsenic in the Rodney Street community are not anticipated to pose an undue health risk to community residents.

7.2.1 Recommendations for Arsenic

1. Residents living on properties with arsenic levels above the MOE guideline should be provided with the MOE Greenfact Sheet entitled "Arsenic in the Environment" which outlines simple measures related to reducing exposure.

7.3 Lead

The weight-of evidence would support an intervention level for exposure reduction of 1,000 µg/g in soils based on:

- empirical findings regarding the potential contribution of soil lead levels to blood lead in children and a blood lead level of concern of 10 µg/dL;
- use of the U.S. EPA Biokinetic model suggest that 1,000 µg/g would provide adequate protection with a margin of safety;
- the new EPA lead in soil standard of 1,200 µg/g suggests that an intervention level of 1,000 µg/g lead in soil would be protective of persons in this community and;
- abatement observations that suggest that only remediation of soils in excess of 1,000 µg/g have a measurable impact on exposure reduction.

In addition, adoption of the U..S. EPA stratified approach to a soil standard seems desirable to focus resources and efforts on those areas which have the highest exposure potential for children. Therefore , an intervention level of 400 µg/g for lead in bare soil play areas is reasonable to apply. Bare soil allows for greater contact of soil particles with children and therefore a more stringent value than 1,000 µg/g is warranted for these specific areas on a property.

7.3.1 Recommendations for Lead

1. An intervention level be established for this community at a soil lead level of 400 µg/g for children's play areas <u>with bare soil</u> on residential properties or in public areas, and at a level of 1,000 µg/g for all other areas of these properties to which children have access.
2. Soil removal, where conducted, should occur to a depth of up to 40 cm. Wet methods of dust control should be employed.
3. Residents living at properties exceeding these intervention levels for lead in soil should

minimize/avoid contact with these soils and not consume vegetables from backyard gardens.

4. All households with measured lead levels above the Ministry screening guideline (200 µg/g) receive the MOE fact sheet on "Lead in Soil" to provide a better understanding of lead exposure and simple measures that can reduce potential exposure.

7.4: Antimony, Beryllium, Cadmium, Cobalt and Copper

For the metals, antimony, beryllium, cadmium, cobalt and copper, estimated total daily intakes for all age classes were well below stringent oral or inhalation exposure limits from major recognized jurisdictions, such as, the US EPA, WHO and Health Canada.

No soil intervention levels for the metals, antimony, beryllium, cadmium, cobalt and copper, in soil in the Rodney Street community are recommended.

8.0 References

The references listed here pertain to the citations contained in this, the main document. Lists of the references used in each of the appendices are provided at the end of each appendix.

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APPENDIX 1

Environmental Monitoring of Metals in Rodney Street and Port Colborne

Drinking Water Monitoring Data

Table A1-1: Summary of Pt. Colborne Municipal Drinking Water Data - 1996 -1999

(Number of Samples = 8)

Element	Range of Drinking Water Concentrations (µg/L)	Average Drinking Water Concentration (µg/L)	MOE Drinking Water Standard (µg/L)	World Health Organization Drinking Water Guidelines (µg/L)	EPA Maximum Contaminant Levels (µg/L)
Treated Drinking Water					
Antimony	0.306 - 0.96	0.5965	none	5 (provisional)	6
Arsenic	0.2 -0.6	0.3394	25	10 (provisional)	5
Beryllium	0.11 - 0.2	0.155	none	none	4
Cadmium	0.0041 - 0.051	0.0224	5	3	5
Cobalt	0.025 - 0.0538	0.0348	none	none	none
Copper	0.333 - 1	0.6534	none	2,000 (provisional)	1,300 (aesthetics)
Lead	0.05 - 1.9	0.3705	10	10	15
Nickel	0.4 - 1.1	0.7686	none	20 (provisional)	none
Distributed Water at Charlotte Street					
Antimony	0.45 - 0.97	0.6445	none	5 (provisional)	6
Arsenic	0.143 - 0.401	0.2767	25	10 (provisional)	5
Beryllium	0.0306 - 0.2	0.1125	none	none	4
Cadmium	0.022 - 0.083	0.0558	5	3	5
Cobalt	0.026 - 0.04	0.0341	none	none	none
Copper	5 - 44.1	14.5	none	2,000 (provisional)	1,300 (aesthetics)
Lead	0.067 - 0.71	0.3834	10	10	15
Nickel	0.6 - 1.3	0.9432	none	20 (provisional)	none

* EPA Region III Risk Based Concentrations are not standards or guidelines and were used for comparison purpose only when the MOE or EPA did not have a standard/guideline for a particular substance.

Table A1-2: Summary of Well and Cistern Data - JWEL - Pt.Colborne - Samples Taken at External Tap

Element	Range of Drinking Water Concentrations (µg/L)	Number of Samples	MOE Drinking Water Standard (µg/L)	World Health Organization Drinking Water Guidelines (µg/L)	EPA Maximum Contaminant Levels (µg/L)
Antimony	<0.5 - <0.6	14	none	5 (provisional)	6
Arsenic	<2 - 3	14	25	10 (provisional)	5
Beryllium	<1	14	none	none	4
Cadmium	<0.1 - 0.2	14	5	3	5
Cobalt	<0.1 - 2.4	14	none	none	none
Copper	2 - 558	14	none	2,000 (provisional)	1,300 (aesthetics)
Lead[1]	0.5 - 3.6	14	10	10	15
Nickel	<1 - 24	14	none	20 (provisional)	none

* EPA Region III Risk Based Concentrations are not standards or guidelines and were used for comparison purpose only when the MOE or EPA did not have a standard/guideline for a particular substance.

[1] One lead sample was measured at 0.0921 mg/L, subsequent confirmatory sampling of the site by JWEL, MOE, and Niagara Regional Health Department resulted in lead levels below the MOE Drinking Water Standard.

Air Monitoring Data

Table A1-3: MOE Air monitoring data (1992-1996) from monitoring station 27047 at Davis & Fraser (ng/ m³)

Year (# of Samples)	Percentiles						Max.	Mean	Geom. Mean
	10%	30%	50%	70%	90%	99%			
1992 (54)	5	5	20	38	130	496	690	53	20
1993 (49)	2	6	10	20	90	302	390	34	13
1994 (48)	4	7	11	21	67	141	160	25	14
1995 (55)	3	8	11	19	49	135	140	23	11
1996 (12)	2	6	10	17	34	62	66	INS	INS

INS = insufficient data

Table A1-4: Summary of Air Monitoring Data for Pt. Colborne

Metal	Minimum Air Concentration (μg/m³)	Maximum Air Concentration (μg/m³)	Average Concentration (μg/m³)	OMOE Air Standard (24-hour)
Ontario Ministry of the Environment - Pt. Colborne Air Monitoring Data - 1992 - 1996				
Nickel	0.002	0.69	0.0327	2
Copper	0.058	0.56	0.112	50
Lead	0.01	0.06	0.02	2
Total Suspended Particulate	9	222	51.66	120
Jacques Whitford Environmental - Air Monitoring Data for Pt. Colborne Schools - Summer 2000				
Arsenic	0.001	0.005	0.002	0.3
Cobalt	0.004	0.01	0.0075	0.1
Copper	0.01	0.08	0.0345	50
Nickel	0.01	0.11	0.05	2
Total Suspended Particulate	24	63	48.67	
PM_{10}	21	44	34	
Environment Canada - Typical Ontario Air Concentrations - 1995 - 1999 (24-hr or annual numbers)				
Antimony	0.0001	0.0115	0.001056	25
Arsenic	0.003	0.0158	0.001644	0.3
Beryllium	No data available			0.01
Cadmium	0.0001	0.0067	0.000711	2
Cobalt	0.001	0.017	0.001967	0.1
Copper	0.001	0.1009	0.018022	50
Lead	0.0005	0.1337	0.0077	2
Nickel	0.0007	0.0351	0.003011	2

Soil Monitoring Data

Table A1-5: Summary of Soil Data for the Rodney Street Area (0-30 cm; based on 1378 sample points)

Chemical	Concentration Range	Median Concentration	Average Concentration	MOE Cleanup Guideline
Aluminum	3,200 - 47,300	17,800.00	17,851.30	None
Antimony	0.275 - 91.1	0.20	1.20	13.00
Arsenic	0.6 - 350	12.70	15.90	20 (25)
Barium	18.5 - 956	157.00	173.10	750 (1000)
Beryllium	0.23 - 4.56	0.97	0.97	1.20
Cadmium	0.14 - 35.325	1.09	1.20	12.00
Calcium	1,920 - 93,400	18,700.00	20,118.00	None
Chromium	6 - 245	29.40	30.20	750 (1000)
Cobalt	3.5 - 262	39.80	50.70	40 (50)
Copper	4.4 - 2,720	200.00	250.20	225 (300)
Iron	8,820 - 130,000	27,300.00	29,529.40	None
Lead	5.9 - 1,800	179.00	221.70	200.00
Magnesium	990 - 31,900	7,220.00	7,780.50	None
Manganese	131 - 5620	480.00	506.10	None
Molybdenum	0.2 - 12.1	4.00	3.81	40.00
Nickel	34.6 - 17,000	1,800.00	2,543.80	150 (200)
Selenium	0.225 - 19.4	0.29	1.29	10.00
Strontium	14.3 - 690	69.10	79.20	None
Vanadium	11 - 74.7	37.10	37.40	200 (250)
Zinc	23 - 1,750	314.00	369.50	600 (800)

Dark shading indicates chemicals considered for evaluation in this risk assessment.
Light shading indicates chemicals which exceed ecological based component of the Cleanup guidelines, but not the human health component and are, therefore, not considered in this risk assessment.

Backyard Garden Vegetable Monitoring Data

Table A1-6: Summary JWEL Vegetable Data - Pt. Colborne - Not Including Rodney Street

Element	Type of Vegetation	Range (Dry Weight (µg/kg))	Number of Samples	Control Range*
Antimony	Orchard Tree Leaves	<0.05 - <0.15	5	No Control
	Orchard Fruit	<0.04 - 0.26	14	Food Store - Apples (<0.08)
	Garden Produce -Roots	<0.05 - <0.1	6	<0.05
	Garden Produce - Vegetable (Fruit)	<0.05 - 0.68	13	<0.1 - 0.1
	Garden Produce - Vegetable (Leafy)	<0.05 - 0.21	8	<0.1 - <0.15
Arsenic	Orchard Tree Leaves	<0.2 - <0.8	5	No Control
	Orchard Fruit	<0.2	14	Food Store - Apples (<0.2)
	Garden Produce -Roots	<0.2	6	<0.2
	Garden Produce - Vegetable (Fruit)	<0.2 - <0.6	13	<0.4
	Garden Produce - Vegetable (Leafy)	<0.2 - <0.6	8	< 0.4 - <0.6
Beryllium	Orchard Tree Leaves	<0.1 - <0.4	5	No Control
	Orchard Fruit	<0.1	14	Food Store - Apples (<0.1)
	Garden Produce -Roots	<0.1	6	<0.1
	Garden Produce - Vegetable (Fruit)	<0.1 - <0.3	13	<0.2
	Garden Produce - Vegetable (Leafy)	<0.1 - <0.3	8	<0.2 - <0.3
Cadmium	Orchard Tree Leaves	<0.01 - 0.22	5	No Control
	Orchard Fruit	<0.01 - 0.13	14	Food Store - Apples <0.01
	Garden Produce -Roots	0.01 - 0.13	6	0.21 - 0.31
	Garden Produce - Vegetable (Fruit)	0.07 - 0.32	13	0.17 - 0.89
	Garden Produce - Vegetable (Leafy)	0.11 - 0.86	8	0.69 - 1.06
Cobalt	Orchard Tree Leaves	<0.01 - 0.22	5	No Control
	Orchard Fruit	<0.01 - 0.14	14	Food Store - Apples (<0.01)
	Garden Produce -Roots	0.02 - 0.09	6	0.02-0.11
	Garden Produce - Vegetable (Fruit)	0.03 - 0.13	13	0.05 - 0.56
	Garden Produce - Vegetable (Leafy)	<0.02 - 0.78	8	0.22 - 0.28
Copper	Orchard Tree Leaves	0.44 - 9.23	5	No Control
	Orchard Fruit	1.57 - 13	14	Food Store only - Apples (2.21)
	Garden Produce -Roots	2.63 - 9.8	6	7.78 -7.93
	Garden Produce - Vegetable (Fruit)	4.56 - 15.6	13	14.9 - 18.7
	Garden Produce- Vegetable (Leafy)	2.78 - 10.6	8	6.54 - 7.21
Lead	Orchard Tree Leaves	0.13 -1.26	5	No Control
	Orchard Fruit	<0.05 - 0.78	14	Food Store only - Apples (<0.05)
	Garden Produce -Roots	0.09 - 0.42	6	0.1 - 0.17
	Garden Produce - Vegetable (Fruit)	<0.1 - 0.68	13	0.13 - 0.15
	Garden Produce - Vegetable (Leafy)	0.1 - 3.92	8	0.23 - 0.35
Nickel	Orchard Tree Leaves	0.4 - 23	5	No Control
	Orchard Fruit	<0.1	14	Food Store only - Apples (<0.1)
	Garden Produce -Roots	0.3 - 1.9	6	0.1 - 0.3
	Garden Produce - Vegetable (Fruit)	0.3 - 12.2	13	0.2 - 4.8
	Garden Produce - Vegetable (Leafy)	1.2 - 12.9	8	0.6

* Control consists of two samples; one purchased at a food store and the other taken from the background control, Wainfleet Bog

Table A1-7: Levels of Antimony in Vegetables from Rodney Street Residences (JWEL,2000)

Location	Antimony Soil Concentration (µg/g)	Vegetable	Dry Weight Antimony Concentration in Vegetable (µg/g)	Conversion Factor (Dry to Fresh weight)	Fresh Weight Antimony Concentration in Vegetable (µg/g)
3	<0.5	Beet Root	0.06	0.13	0.0078
		Celery	<0.05	0.059	-
		Tomato	<0.1	0.065	-
9	Not analyzed	Tomato	<0.1	0.065	-
25	1.1	Pepper	<0.1	0.066	-
		Lettuce	0.46	0.045	0.021
		Beet Root	<0.1	0.13	-
33	Not analyzed	Lettuce	<0.1	0.045	-
		Pepper	<0.05	0.066	-
34	Not analyzed	Radish	<0.05	0.055	-
		Pepper	0.27	0.066	0.018
41	Not analyzed	Tomato	<0.1	0.065	-
MOE Samples					
Sample #1		Tomato		0.065	
		Green Pepper		0.066	
Sample #2		Pepper		0.066	
		Tomato		0.065	
Control Samples					
Food Store Control		Beet	<0.05	0.13	-
		Pepper	<0.1	0.066	-
		Lettuce	<0.15	0.045	-
Wainfleet Bog (Background Control)		Beet Root	<0.05	0.13	-
		Pepper	<0.1	0.066	0.0066
		Beet Top	<0.1	0.091	-

Table A1-8: Levels of Beryllium inVegetables from Rodney Street Residences (JWEL, 2000)

Location	Beryllium Soil Concentration (μg/g)	Vegetable	Dry Weight Beryllium Concentration in Vegetable (μg/g)	Conversion Factor (Dry Weight to Fresh Weight)	Fresh Weight Beryllium Concentration in Vegetable (μg/g)
3	0.7	Beet Root	<0.1	0.13	-
		Celery	<0.1	0.059	-
		Tomato	<0.1	0.065	-
9	Not Analyzed	Tomato	<0.2	0.065	-
25	0.5	Pepper	<0.2	0.066	-
		Lettuce	<0.2	0.045	-
		Beet Root	<0.1	0.13	-
33	Not Analyzed	Lettuce	<0.2	0.045	-
		Pepper	<0.1	0.066	-
34	Not Analyzed	Radish	<0.1	0.055	-
		Pepper	<0.3	0.066	-
41	Not Analyzed	Tomato	<0.2	0.065	-
MOE Samples					
Sample #1	0.75	Tomato	0.1	0.065	0.0065
		Green Pepper	0.1	0.066	0.0066
Sample #2	0.425	Pepper	0.1	0.066	0.0066
		Tomato	0.1	0.065	0.0065
Control Samples					
Food Store Control	n/a	Beet	<0.1	0.13	-
		Pepper	<0.2	0.066	-
		Lettuce	<0.3	0.045	-
Wainfleet Bog (Background Control)	0.5	Beet Root	<0.1	0.13	-
		Pepper	<0.2	0.066	-
		Beet Top	<0.2	0.091	-

Table A1-9: Levels of Cadmium in Vegetables from Rodney Street Residences (JWEL, 2000)

Location	Cadmium Soil Concentration (µg/g)	Vegetable	Dry Weight Cadmium Concentration in Vegetable (µg/g)	Conversion Factor (Dry Weight to Fresh Weight)	Fresh Weight Cadmium Concentration in Vegetable (µg/g)
3	<0.5	Beet Root	0.38	0.13	0.049
		Celery	0.85	0.059	0.050
		Tomato	0.23	0.065	0.015
9	Not Analyzed	Tomato	0.13	0.065	0.0085
25	1.1	Pepper	0.15	0.066	0.0099
		Lettuce	0.34	0.045	0.013
		Beet Root	0.24	0.13	0.031
33	Not Analyzed	Lettuce	0.45	0.045	0.020
		Pepper	0.22	0.066	0.015
34	Not Analyzed	Radish	0.16	0.055	0.0088
		Pepper	0.28	0.066	0.018
41	Not Analyzed	Tomato	0.13	0.065	0.0085
MOE Samples					
Sample #1	0.8	Tomato	0.2	0.065	0.013
		Green Pepper	0.05	0.066	0.0033
Sample #2	0.1	Pepper	0.2	0.066	0.013
		Tomato	0.2	0.065	0.013
Control Samples					
Food Store Control	n/a	Beet	0.21	0.13	0.027
		Pepper	0.17	0.066	0.011
		Lettuce	1.06	0.045	0.048
Wainfleet Bog (Background Control)	15.4-15.8	Beet Root	0.31	0.13	0.040
		Pepper	0.89	0.066	0.059
		Beet Top	0.69	0.091	0.063

Table A1-10: Levels of Cobalt in Vegetables from Rodney Street Residences (JWEL,2000)

Location	Cobalt Soil Concentration (µg/g)	Vegetable	Dry Weight Cobalt Concentration in Vegetable (µg/g)	Conversion Factor (Dry Weight to Fresh Weight)	Fresh Weight Cobalt Concentration in Vegetable (µg/g)
3	20.1	Beet Root	0.37	0.13	0.048
		Celery	0.14	0.059	0.083
		Tomato	0.09	0.065	0.0059
9	Not Analyzed	Tomato	0.06	0.065	0.0039
25	28.6	Pepper	0.05	0.066	0.0033
		Lettuce	0.1	0.045	0.0045
		Beet Root	0.11	0.13	0.014
33	Not Analyzed	Lettuce	0.33	0.045	0.015
		Pepper	0.04	0.066	0.0026
34	Not Analyzed	Radish	0.13	0.055	0.0072
		Pepper	<0.03	0.066	-
41	Not Analyzed	Tomato	0.04	0.065	0.0026
MOE Samples					
Sample #1	44.5	Tomato	0.1	0.065	0.0065
		Green Pepper	0.1	0.066	0.0066
Sample #2	58	Pepper	0.1	0.066	0.0066
		Tomato	0.1	0.065	0.0065
Control Samples					
Food Store	Control	Beet	0.02	0.13	0.0026
		Pepper	0.05	0.066	0.0033
		Lettuce	0.28	0.045	0.013
Wainfleet Bog (Background Control)	4.5	Beet Root	0.11	0.13	0.014
		Pepper	0.56	0.066	0.037
		Beet Top	0.22	0.091	0.020

Table A1-11: Levels of Arsenic inVegetables from Rodney Street Residences (JWEL, 2000)

Location	Arsenic Soil Concentration (µg/g)	Vegetable	Dry Weight Arsenic Concentration in Vegetable (µg/g)	Conversion Factor (Dry Weight to Fresh Weight)	Fresh Weight Arsenic Concentration in Vegetable (µg/g)
3	<0.2	Beet Root	<0.2	0.13	-
		Celery	<0.2	0.059	-
		Tomato	<0.4	0.065	-
9	Not Analyzed	Tomato	<0.4	0.065	-
25	18.6	Pepper	<0.4	0.066	-
		Lettuce	<0.4	0.045	-
		Beet Root	<0.4	0.13	-
33	Not Analyzed	Lettuce	<0.4	0.045	-
		Pepper	<0.2	0.066	-
34	Not Analyzed	Radish	0.2	0.055	0.011
		Pepper	<0.6	0.066	-
41	Not Analyzed	Tomato	<0.4	0.065	-
MOE Samples					
Sample #1	13	Tomato	0.1	0.065	0.0065
		Green Pepper	0.1	0.066	0.0066
Sample #2	17.5	Pepper	0.1	0.066	0.0066
		Tomato	0.1	0.065	0.0065
Control Samples					
Food Store (Control)		Beet	<0.2	0.13	-
		Pepper	<0.4	0.066	-
		Lettuce	<0.6	0.045	-
Wainfleet Bog (Background Control)	1.3 - 1.4	Beet Root	<0.2	0.13	-
		Pepper	<0.4	0.066	-
		Beet Top	<0.4	0.091	-

Table A1-12: Levels of Copper inVegetables from Rodney Street Residences (JWEL, 2000)

Location	Copper Soil Concentration (µg/g)	Vegetable	Dry Weight Copper Concentration in Vegetable (µg/g)	Conversion Factor (Dry Weight to Fresh Weight)	Fresh Weight Copper Concentration in Vegetable (µg/g)
3	134	Beet Root	14.8	0.13	1.92
		Celery	5.14	0.059	0.30
		Tomato	10.1	0.065	0.66
9	Not Analyzed	Tomato	11.3	0.065	0.73
25	194	Pepper	10.4	0.066	0.67
		Lettuce	11.8	0.045	0.53
		Beet Root	9.71	0.13	1.26
33	Not Analyzed	Lettuce	8.81	0.045	0.40
		Pepper	7.09	0.066	0.47
34	Not Analyzed	Radish	5.2	0.055	0.29
		Pepper	1.6	0.066	1.06
41	Not Analyzed	Tomato	7.93	0.065	0.52
MOE Samples					
Sample #1	220	Tomato	4.9	0.065	0.32
		Green Pepper	5.9	0.066	0.39
Sample #2	325	Pepper	9.4	0.066	0.62
		Tomato	4.6	0.065	0.30
Control Samples					
Food Store (Control)		Beet	7.78	0.13	1.01
		Pepper	18.7	0.066	1.23
		Lettuce	6.54	0.045	0.29
Wainfleet Bog (Background Control)	14.9-22.2	Beet Root	7.93	0.13	1.03
		Pepper	14.9	0.066	0.98
		Beet Top	7.21	0.091	0.66

Table A1-13: Levels of Lead in Vegetables from Rodney Street Residences (JWEL, 2000)

Location	Lead Soil Concentration (µg/g)	Vegetable	Dry Weight Lead Concentration in Vegetable (µg/g)	Conversion Factor (Dry Weight to Fresh Weight)	Fresh Weight Lead Concentration in Vegetable (µg/g)
3	379	Beet Root	6.26	0.13	0.81
		Celery	4.16	0.059	0.25
		Tomato	0.1	0.065	0.0065
9	Not Analyzed	Tomato	0.12	0.065	0.0078
25	371	Pepper	0.15	0.066	0.0099
		Lettuce	0.93	0.045	0.042
		Beet Root	8.11	0.13	1.05
33	Not Analyzed	Lettuce	2.43	0.045	0.11
		Pepper	2.55	0.066	0.17
34	Not Analyzed	Radish	2.55	0.055	0.14
		Pepper	0.58	0.066	0.038
41	Not Analyzed	Tomato	<0.1	0.065	-
MOE Samples					
Sample #1	91.5	Tomato	0.25	0.065	0.016
		Green Pepper	0.25	0.066	0.017
Sample #2	88	Pepper	0.6	0.066	0.040
		Tomato	1.9	0.065	0.12
Control Samples					
Food Store Control	n/a	Beet	0.17	0.13	0.022
		Pepper	0.13	0.066	0.0086
		Lettuce	0.23	0.045	0.010
Wainfleet Bog (Background Control)	10.9 - 11	Beet Root	0.1	0.13	0.013
		Pepper	0.15	0.066	0.0099
		Beet Top	0.35	0.091	0.032

APPENDIX 2

Toxicity Assessment

APPENDIX 2: TABLE OF CONTENTS

LIST OF TABLES

Toxicity Assessment

A2-1 Introduction

The chemical screening section of the main report identified eight metals as being potential human health concerns in the Rodney Street area of Port Colborne. The objectives of the toxicity assessment are;

- to provide the reader with a brief understanding of the toxicological effects that have been reported to be associated with exposure to the chemicals of concern;
- to identify whether each metal of concern should be considered as being carcinogenic or non-carcinogenic and;
- to identify suitable exposure limits against which exposures can be compared to provide estimates of potential health risks.

The toxicological profiles are **not** intended to;

- be exhaustive examinations of all the toxicological information available for each metal;
- be used to develop exposure limits for exposure routes where no exposure limits are available, or;
- critically review and/or modify currently existing exposure limits.

This toxicity assessment outlines the toxicological effects that have been reported to be associated with inhalation, ingestion and dermal contact exposures to antimony, arsenic, beryllium, cadmium, cobalt, copper, lead and nickel, and identify whether each metal should be considered as a carcinogen or a non-carcinogen. The type of exposure limit selected is dependent upon whether a compound is considered to be non-carcinogenic or carcinogenic. The types of exposure limits associated with both types of compounds are discussed below.

The toxicological profiles also examine the effect that the route of exposure has on the toxicological activity of each compound. For some compounds, the route by which the compound enters the body can have a marked effect on the toxicological effects that occur. In cases where the toxicological effects of a chemical differ between the routes of exposure, it is necessary to assess inhalation and ingestion exposures independently. For example, arsenic, beryllium, cadmium and nickel inhalation exposures may be carcinogenic, but are not carcinogenic by ingestion exposure. Therefore, where route-specific exposure limits are available, the toxicological profiles will provide both. In cases where exposure limits are available for a single route of exposure, the toxicological profiles will not develop exposure limits by route-to-route extrapolation. Although route-to-route extrapolation is undertaken in some situations, it is discouraged by the US EPA and similar regulatory agencies because it requires detailed knowledge of pharmacokinetic and pharmacodymanic factors and extensive modelling. All of which are beyond the scope of the current assessment.

The references used in the development of each toxicological profile are provided at the end of each profile.

A2-1.1 Exposure Limits for Non-Carcinogenic Compounds.

Non-carcinogenic compounds are generally considered to act on the body through threshold mechanisms. This means that at low doses the body is able to remove the compounds from the body without the compounds causing adverse or toxic effects. As the dose or exposure to a compound increases, the body's ability to clear the compound is reduced. When exposure exceeds the body's ability to process and excrete the compound, it can cause adverse or toxic effects. The point at which this occurs is called the threshold. The threshold is different for every compound. The exposure limits developed for each compound reflect the threshold for each chemical.

The US EPA is a reliable source of exposure limits or *Reference Doses* RfDs for ingestion exposures and *Reference Concentration (RfCs)* for inhalation exposures, that are developed from toxicological studies of human or animal populations. These are set to ensure that chronic exposures to a chemical at concentrations that are at or below the exposure limit will not result in adverse effects. The US EPA defines the RfD/Rf C as;

> *A quantitative estimate (with uncertainty spanning perhaps an order of magnitude) of a daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of non-carcinogenic, deleterious effects during a life-time.*

The US EPA RfD/RfC values are based on life-time averaged exposures. This means that limited exposures to a compound that exceed an exposure limit will not result in adverse effects, provided that over a life-time, the averaged daily dose does not exceed the exposure limit. The exposure limit is set to prevent the accumulation of the compound in the body at levels that exceed the threshold and therefore limit the possibility of adverse health effects occurring.

The RfD/RfC values are intended to be used as life-time average daily exposures and therefore, in assessing potential risks for an exposed individual or population, life-time averaged daily doses should be used if the exposures are expected to occur over a life-time. The US EPA *Risk Assessment Guidance for Superfund (RAGS)* recommends that in the assessment of risks associated with exposures to non-carcinogenic compounds that life-time averaged exposures be used to assess risks when exposures occur over a life-time (RAGS, 1989[1]). The RAGS further notes that the comparison of short-term or non-life-time exposures to RfD/RfC values should only be used as a screening exercise to determine if a potential human health risk would be predicted based on estimated exposures. Short-term exposures that are below the chronic exposure limit, concern for adverse human health effects is low (RAGS, 1989). Life-time averaged daily doses (LADD) are calculated as shown in equation A2-1.

Eq A2-1

$$LADD = \sum_{1}^{n} \frac{(Intake_{(1..n)} \times Time_{(1..n)})}{(B.W._{(1..n)} \times 70 years)}$$

1 US EPA, 1989. Risk Assessment Guidance for Superfund Volume 1 Human Health Evaluation Manual (Part A), US EPA, EPA/540/1-89/002

A2-1.2 Exposure Limits for Carcinogenic Compounds

Carcinogenic compounds are generally considered to work through a non-threshold mechanism which means that there is no dose below which an adverse effect will not occur. Any exposure to a carcinogen is considered to be associated with some level of risk. At very low doses, the probability that an adverse effect (cancer) will occur is extremely small. The probability of developing cancer increases as the dose increases. Incremental increases in life-time cancer risk (ILCR) are estimated by comparing the established potency for each compound with the calculated LADD for that compound.

The US EPA is a reliable source of estimates of carcinogenic potency for numerous chemicals. The US EPA expresses carcinogenic potencies as cancer slope factors (*Risk per (μg/kg body weight-day))* or as a *Unit Risk (UR* $(\mu g/m^3)^{-1}$*)* for inhalation exposures or *(UR* $(\mu g/L)^{-1}$*)* for exposures to chemicals in drinking water. The slope factor is defined by the US EPA as;

> *An upper-bound on a maximum likelihood estimate developed from dose-response data using one of several models incorporating low-dose linearity.*

The *Unit Risk* is defined as;

> *The upper-level increased likelihood that an individual will develop cancer when exposed to a chemical over a life-time at a concentration of 1 μg/L in drinking water or 1* $\mu g/m^3$ *in air for a continuous inhalation exposure.*

Health Canada provides cancer potency estimates as Tumorigenic Doses (TD_{05}). These values represent life-time exposure levels that would result cancers in 5% of the population.

In this document, the term *μg/kg body weight-day* will be abbreviated as μg/kg-day.

A2-2 Toxicological Profile for Antimony

The health risk of antimony (Sb) exposure in Ontario soils has been assessed for Port Hope (MOE, 1991). This appendix updates MOE (1991).

Antimony is a naturally occurring metal that is used in various manufacturing processes. It is generally found as a sulphide or oxides. The natural sulfide of antimony was known and used in Biblical times as medicine and as a cosmetic. The most important use of antimony metal is as a hardener in lead for storage batteries. The metal also finds applications in solders and other alloys. Antimony trioxide is the most important of the antimony compounds and is primarily used in flame-retardant formulations. These flame-retardant applications include such markets as children's clothing, toys, aircraft and automobile seat covers.

A2-2.1 Pharmacokinetics

Exposure to antimony may be via inhalation, oral and dermal routes (ATSDR, 1990). Antimony is sparingly absorbed following ingestion or inhalation (Felicetti et al., 1974; Gerber et al., 1982; US EPA, 1998). Both gastrointestinal and pulmonary absorption are a function of compound solubility. Trivalent antimony is more readily absorbed than pentavalent forms. Antimony is transported in the blood. Antimony is not metabolized but may bind to macromolecules and react covalently with sulfhydryl and phosphate groups (ATSDR, 1990). Excretion of antimony is primarily via the urine and feces (Cooper et al., 1968; Ludersdorf et al., 1987; ATSDR, 1990).

A2-2.2 Toxicology

A2-2.2.1 Non-Cancer Effects

Acute oral exposure of humans and animals to high doses of antimony or antimony-containing compounds (antimonials) may cause gastrointestinal disorders (vomiting, diarrhea), respiratory difficulties, and death at extremely high doses (Bradley and Frederick, 1941; Beliles, 1979; ATSDR, 1990). Subchronic and chronic oral exposure may affect hematologic parameters (ATSDR, 1990). Long-term exposure to high doses of antimony or antimonials has been shown to adversely affect longevity in animals (Schroeder et al., 1970). Limited data suggest that prenatal and postnatal exposure of rats to antimony interferes with vasomotor responses (Marmo et al., 1987; Rossi et al., 1987).

Acute occupational exposure may cause gastrointestinal disorders (probably due to ingestion of airborne antimony) (ATSDR, 1990). Exposure of animals to high concentrations of antimony and antimonials (especially stibine gas) may result in pulmonary edema and death (Price et al., 1979). Long-term occupational exposure of humans has resulted in electrocardiac disorders, respiratory disorders, and possibly increased mortality (Renes, 1953; Breiger et al., 1954). Antimony levels for these occupational exposure evaluations ranged from 2,200 to 11,980 μg Sb/m^3. Based on limited data, occupational exposure of women to metallic antimony and several antimonials has reportedly caused alterations in the menstrual cycle and an increased incidence of spontaneous abortions

(Belyaeva, 1967). Reproductive dysfunction has been demonstrated in rats exposed to antimony trioxide (Belyaeva, 1967).

No data were available indicating that dermal exposure of humans to antimony or its compounds results in adverse effects. Eye irritation due to exposure to stibine gas and several antimony oxides has been reported for humans (Stevenson, 1965; Potkonjak and Pavlovich, 1983).

A2-2.2.2 Cancer Effects

The U.S. EPA has not evaluated antimony or antimonials for carcinogenicity.

A2-2.2.3 Susceptible Populations

No studies were located regarding unusual susceptibility of any human subpopulation to antimony. A susceptible population will exhibit a different or enhanced response to antimony than will most persons exposed to the same level of antimony in the environment. Reasons include genetic make-up, developmental stage, health and nutritional status, and chemical exposure history. These parameters result in decreased function of the detoxification and excretory processes (mainly hepatic and renal) or the pre-existing compromised function of target organs. For these reasons the elderly with declining organ function and the youngest of the population with immature and developing organs are expected to be generally be more vulnerable to toxic substances than healthy adults (ATSDR, 1993).

A2-2.3 Current Exposure Limits
A2-2.3.1 Oral Exposure Limits

The U. S. EPA (U.S. EPA, 1991) has calculated subchronic and chronic oral reference doses (RfDs) of 0.4 µg/kg-day based on decreased longevity and alteration of blood chemistry in rats chronically exposed to potassium antimony tartrate in the drinking water (5 ppm equivalent to 350 µg Sb/kg-day) (Schroeder et al, 1970). More recently, the NRC has proposed an oral RfD for antimony trioxide of 200 µg/kg-day based on increases in serum enzymes and liver weight in female rats in the study of Hext et al (1999)(NRC, 2000)

A2-2.3.2 Inhalation Exposure Limits

The U. S. EPA (IRIS, 1998) has calculated a reference concentration for chronic inhalation exposure (RfC) of 0.2 µg / m^3 based on pulmonary toxicity and chronic interstitial inflammation in a one year inhalation toxicity study in rats exposed to antimony trioxide (Newton et al., 1994). This RfC was also proposed by the NRC (NRC, 2000).

A2-2.3.3 Selection of Exposure Limits

The exposure limits used to assess the potential risks associated with ingestion and inhalation exposures to antimony are summarized in Table A2-1

Table A2-1: Selected Exposure Limits for Antimony

Route of Exposure	Exposure Limit	Toxicological Basis	Source Agency
Non-Cancer Effects			
Ingestion	0.4 µg/kg-day	decreased longevity and altered blodd chemistry in rats	EPA, 1998
Inhalation	0.2 µg /m^3	pulmonary toxity in rats	EPA, 1998
Dermal Contact			
Cancer Effects			
Ingestion	N.A.[1]		
Inhalation	N.A.		
Dermal Contact	N.A.		

1. Not Applicable

A2-2.4 Antimony References

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World Health Organization (WHO). 1996. Antimony. Guidelines for drinking-water quality, 2nd ed. Vol. 2 Health criteria and other supporting information. WHO, Geneva. pp. 147-156.

A2-3 Toxicological Profile for Arsenic

Arsenic (As) is a brittle, gray metal that tarnishes in air. It is a natural component of the earth's crust and occurs in small amounts in rock, soil, water and underwater sediments. It is commonly found in combination with sulfur and iron in minerals such as arseno-pyrite. Arsenic is used mainly to preserve wood and to control insects and weeds.

Elemental arsenic is not soluble in water; calcium arsenate, and calcium arsenites are sparingly soluble in water; the remaining arsenicals are soluble in water. Arsenic, arsenic pentoxide, arsenic trioxide, the calcium arsenites, lead arsenate, and potassium arsenate are soluble in various acids (ATSDR, 1993).

A2-3.1 Pharmacokinetics

The oral bioavailability of arsenic compounds is dependent on the chemical species and on the matrix (e.g. soil or dust) in which it is administered. Based on published literature, the absorption of water-soluble inorganic arsenic compounds in an aqueous solution is about 95 percent. For soil and house dust containing arsenic the absorption is about 14 and 19 percent respectively. The bioavailability of inorganic arsenic for exposure via inhalation would be in the range of 30 – 34 percent. The dermal absorption in humans range from 0.8 to 1.9 percent (ATSDR, 1993).

Distribution of arsenic within the body is affected by the route through which exposure occurs. Given sufficient time for equilibration, arsenic generally tends to be evenly distributed amongst tissues within the body. The interaction of arsenic with various tissues is dependent on the chemical form of the arsenic. The primary pathway of elimination of inorganic arsenic is excretion via the urine. Because of the importance of urinary excretion as the primary route of elimination of arsenic, concentrations of arsenic compounds in the urine is considered to be a reliable index of recent exposure to arsenic (ATSDR, 1993).

A2-3.2 Toxicology

A2-3.2.1 Non-Cancer Effects

There are numerous studies that have looked at human exposures to inorganic arsenic in the air, but there are no reports of fatalities associated with short-term occupational exposures to arsenic levels as high as 100 mg As/m^3 (ATSDR, 1993).

Inhalation exposures to inorganic arsenic dusts in the workplace have been reported to cause irritation of the nose and throat, laryngitis, bronchitis and cases of very high exposures have been reported to result in perforation of the nasal septum (ATSDR, 1993). However, respiratory effects have not been noted at exposure levels that range between 0.1 and 1.0 mg/m^3 (ATSDR, 1993). There is some limited evidence of respiratory tract effects following oral exposure to inorganic arsenic, but this is thought to be a secondary effect that is due to the vascular damage which results from the ingestion of arsenic (ATSDR, 1993).

There is limited and equivocal epidemiological evidence that suggests that inhalation exposures to arsenic trioxide dust may result in cardiovascular effects. However, there are a number of studies that indicate that oral exposures to inorganic arsenic can lead to serious damage of the cardiovascular system (ATSDR, 1993). Both acute and long-term exposures can result in myocardial depolarization and cardiac arrhythmias. Long-term exposures to low levels of arsenic can also result in damage to the vascular system, characterized by a progressive loss of circulation in the hands and feet (ATSDR, 1993). In areas of Taiwan, with elevated levels of arsenic in the drinking water, evidence of circulatory effects related to arsenic exposures begin to occur at a dose of approximately 0.014 mg As/kg-day (ATSDR, 1993).

There are several studies that have indicated that inhalation exposures to inorganic arsenic can lead to a number of neurological effects in humans, including; peripheral neuropathy of sensory and motor neurons that are manifested as numbness, loss of reflexes and muscle weakness. In extreme cases, frank encephalopathy including, hallucinations and memory loss have been reported (ATSDR, 1993). There effects generally cease once exposures have ended (ATSDR, 1993).

Acute effects of oral arsenic exposure include vomiting, nausea, diarrhea, gastrointestinal haemorrhage, and death. There are a large number of cases of human fatalities following the ingestion of inorganic arsenicals. In most cases, the doses resulting in death have been difficult to quantify. However, two reports, indicate that doses ranging between 1 and 22 mg As per kg body weight per day (mg/kg-day) have resulted in death. Although similar effects are often seen with long-term exposures to lower doses of arsenic, effects are not generally reported at doses lower than 0.01 mg As/kg-day (ATSDR, 1993).

There are a large number of studies that indicate that the acute ingestion of large amounts of inorganic arsenic can cause a number of injuries to the nervous system including; headache, lethargy, mental confusion, hallucination, seizures and in extreme cases, coma (ATSDR, 1993). Chronic exposures to lower levels of arsenic, ranging between 0.019 and 0.5 mg/kg-day, are typically characterized by a peripheral neuropathy similar to that seen with inhalation exposures. Neurological effects have not been detected in populations chronically exposed to arsenic levels of less than 0.01 mg/kg-day (ATSDR, 1993).

A number of hematological effects including anemia and leukopenia have been reported in humans as a result of acute, intermediate and chronic oral exposures to arsenic (ATSDR, 1993). These effects are usually not seen in persons exposed to levels of arsenic lower than 0.07 mg/kg-day (ATSDR, 1993).

Oral exposures to inorganic arsenic have been reported to cause several toxic effects in the liver including, elevated levels of hepatic enzymes in the blood, portal tract fibrosis and swelling of the liver (ATSDR, 1993). These effects are generally seen in cases where chronic exposures range between 0.019 to 0.1 mg/kg-day (ATSDR, 1993). It has been suggested by several researchers that these effects are secondary to the damage of hepatic blood vessels resulting from the damaging effects that inorganic arsenic has on the circulatory system. However, there is insufficient clinical information available to confirm this (ATSDR, 1993).

There is little clinical evidence of renal damage following oral exposures to inorganic arsenic

compounds (ATSDR, 1993). A few cases of renal failure have been reported in cases of arsenic poisoning, but this is felt to be due to fluid imbalances of vascular damage caused by arsenic, and not directly attributable to arsenic (ATSDR, 1993).

The most common dermal effect associated with the ingestion of inorganic arsenic is the development of a pattern of skin changes which include; hyperkeratosis, the development of hyperkeratotic warts, areas of hyperpigmentation and hypopigmentation (ATSDR, 1993). Numerous studies have shown that dermal effects are common in humans exposed to inorganic arsenic levels that range between 0.01 and 0.1 mg As/kg-day. These studies have also demonstrated that, below a dose level of 0.01 mg As/kg-day, dermal effects are not reported (ATSDR, 1993).

A2-3.2.2 Cancer Effects

There is sufficient convincing epidemiological evidence to show that inhalation exposure to inorganic arsenic can increase the risk of developing lung cancer. Many studies provide only qualitative evidence of an association between the duration of and/or level of exposure to arsenic and the increase in the rate of lung cancer. There is sufficient epidemiological information available from occupational studies for the US EPA to develop cancer potency estimates for inhalation exposures to inorganic arsenic (USEPA, 1995).

There are a large number of epidemiological studies that provide convincing evidence that the ingestion of inorganic arsenic increases the risk of developing skin cancer. The most common effect is the development of squamous cell carcinomas. Basal cell carcinomas also occur. In the majority of cases, skin cancer only develops after prolonged exposure (ATSDR, 1993). There is sufficient human epidemiological data available for the US EPA to develop estimates of cancer risk associated with oral exposure to inorganic arsenic (USEPA, 1995).

A2-3.2.3 Susceptible Populations

No studies were located regarding unusual susceptibility of any human subpopulation to arsenic. A susceptible population will exhibit a different or enhanced response to arsenic than will most persons exposed to the same level of arsenic in the environment. Reasons include genetic make-up, developmental stage, health and nutritional status, and chemical exposure history. These parameters result in decreased function of the detoxification and excretory processes (mainly hepatic and renal) or the pre-existing compromised function of target organs. For these reasons the elderly with declining organ function and the youngest of the population with immature and developing organs are expected to be generally be more vulnerable to toxic substances than healthy adults (ATSDR, 1993).

A2-3.3 Current Exposure Limits

A2-3.3.1 Oral Exposure Limits

The USEPA (1998) calculated an oral RfD of 0.3 μg As/kg-dayay based on epidemiological

studies of chronic exposure to arsenic throμgh drinking water. This limit was selected for non-carcinogenic effects.

Arsenic exposure via the oral route was considered to be carcinogenic to humans, based on the incidence of skin cancers in epidemiological studies examining human exposure through drinking water. The cancer slope factor of 0.0015 (μg As/kg-dayay)$^{-1}$ and corresponding risk specific dose (RSD) of 0.00067 μg As/kg-dayay are based on an acceptable risk level of one-in-one million.

A2-3.3.2 Inhalation Exposure Limits

The USEPA (1998) calculated an inhalation unit risk for arsenic of 0.0043 (μg/m^3)$^{-1}$ based on epidemiological studies of lung cancer in workers at arsenic smelters (EPA, 1999).

A2-3.3.3 Selection of Exposure Limits

The estimates of the carcinogenic potencies of inhaled and ingested inorganic arsenic, developed by the US EPA can be used to assess potential human health risks associated with exposure to inorganic arsenic at this site. The potency estimates established by the US EPA and the health effects upon which they are based are summarized below.

Table A2-2: Selected Exposure Limits for Arsenic

Route of Exposure	Exposure Limit	Toxicological Basis	Source Agency
Non-Cancer Effects			
Ingestion	0.30 μg/kg-day		US EPA, 1998
Inhalation	N.A.[1]		
Cancer Effects			
Ingestion	N.A.[1]		
Inhalation	4.3×10^{-3} (μg/m^3)$^{-1}$	Lung Cancer	USEPA, 1998

1. Not Applicable

A2-3.4 Arsenic References

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A2-4 Toxicological Profile for Beryllium

Beryllium (Be) is a hard, grayish, odourless metal. The element occurs naturally as a chemical component of certain rocks, coal and oil, volcanic dust, and soil. Two kinds of mineral rocks, bertrandite and beryl, are mined commercially for the recovery of beryllium. (ATSDR, 1993). Beryllium is used in beryllium-copper alloys, in microelectronics, in aerospace technology, as a solid-propellant in rocket fuels (Lewis, 1993), in aircraft brakes, in X-ray windows, and in neutron reflectors (Ashford, 1994).

A2-4.1 Pharmacokinetics

Inhaled beryllium is absorbed through the lungs, however insufficient data are available to determine the rate and extent of absorption. The biological half-life of beryllium in serum is estimated to be between 2 to 8 weeks.

Toxicity through oral exposure is not very likely since animal studies show that beryllium is not efficiently absorbed through the gastrointestinal tract. Soluble salts are precipitated by reaction with proteins in the alimentary tract (Browning, 1969). No human data are available regarding the absorption of beryllium after oral exposure.

Beryllium does not appear to be absorbed through intact skin as exposed workers only demonstrated skin rashes and ulcerations when the skin was cut accidently.

A2-4.2 Toxicology

A2-4.2.1 Non-Cancer Effects

The effects of exposure to beryllium via inhalation depends on how much you are exposed to and for how long. Inhalation of high concentrations of soluble beryllium compounds has caused pneumonia in occupationally exposed workers. Chronic inhalation exposure to somewhat lower concentrations can lead to an obstructive lung disease known as chronic beryllium disease (CBD). Chronic beryllium disease is caused by genetically regulated cell-mediated immune responses (US EPA, 1998; Chang, 1996).

Swallowing beryllium has not been reported to cause effects in humans because very little beryllium can move from the stomach and intestines into the bloodstream. No human data are available regarding ingestion of beryllium, however animal studies show lesions on the stomach as well as the small and large intestines as the result of ingestion of beryllium sulphate in the diet.

Skin lesions have been reported in a few individuals occupationally exposed to beryllium. Skin ulceration occurred only if the skin had been accidently cut.

A2-4.2.2 Cancer Effects

Several epidemiological studies show an increase incidence of lung cancer deaths amongst workers employed at beryllium factories (ATSDR, 2000). However, historical exposure levels were not reported so no correlation could be drawn between the incidence of lung cancer deaths and beryllium exposure.

The United States Environmental Protection Agency classifies *inhaled* beryllium and beryllium compounds as a probable human carcinogen (Group B1) based on limited evidence for humans and sufficient data for animals (US EPA, 1998). The United States Environmental Protection Agency also indicates that there are no studies on the potential carcinogenicity of ingested beryllium for humans and that the available animal studies do not indicate that adverse effects (US EPA, 1998). The United States National Toxicology Program classifies beryllium and compounds as reasonably anticipated carcinogens (NTP, 2001).

The International Agency for Research on Cancer has classified beryllium and beryllium compounds as carcinogenic to humans (Group 1) based on sufficient animal and human data.

A2-4.2.3 Susceptible Populations

A genetic predisposition for a human leukocyte antigen (HLA) class II may make some individuals more susceptible to chronic beryllium disease. Other factors which may increase susceptibility to beryllium are lowered adrenal gland or liver function.

A2-4.3 Current Exposure Limits
A2-4.3.1 Oral Exposure Limits

The United States Environmental Protection Agency has developed an oral reference dose of 2.0 μg/kg-day for beryllium (US EPA, 1998). The reference dose is based on a benchmark dose derived from dose response modelling of data for a study of lesions on the small intestines of dogs (Morgareidge et al, 1976). A benchmark dose is the dose at the 95% confidence interval of a dose-response model and corresponds to a 10% increase in effects (stomach lesions) in comparison to the control population. An uncertainty factor of 300 (10 for interspecies differences, 10 for differences in human populations and 3 for database deficiencies) was applied to the benchmark dose to determine the reference dose.

ATSDR has developed an minimal risk level for beryllium based on the same dog study (Morgareidge et al, 1976) of 1.0 μg beryllium/kg-day. The MRL was determined by applying an uncertainty factor of 100 to the no-observed-adverse-effect (NOAEL) at 100 μg beryllium/kg-day.

A2-4.3.2 Inhalation Exposure Limits

The US EPA (US EPA, 1998) has developed an inhalation RfC of 0.02 $\mu g/m^3$ based on

beryllium sensitization and progression to chronic beryllium disease in beryllium workers (Kreiss et al., 1996) and the Eisenbud et al. (1949) study of community residents living near a beryllium plant..

The US EPA (US EPA, 1998) has developed an inhalation unit risk of 0.0024 $(\mu g/m^3)^{-1}$ based on lung cancer mortality in male beryllium manufacturing workers (Wagoner et al., 1980). The air concentration at the 10^{-5} and 10^{-6} lifetime cancer risk levels are 0.004 $\mu g/m^3$ and 0.0004 $\mu g/m^3$, respectively.

Health Canada (1996) has determined a tumorigenic dose (TD_{05}) of 5.1 $\mu g/m^3$ for inorganic beryllium compounds. This TD_{05} can be divided by 5000 to obtain a 10^{-5} lifetime cancer risk air concentration of 0.001 $\mu g/m^3$.

A2-4.3.3 Selection of Exposure Limits

The estimates of the carcinogenic potencies of inhaled and ingested beryllium, developed by the US EPA will be used to assess potential human health risks associated with exposure to beryllium at this site. The potency estimates established by the US EPA and the health effects upon which they are based are summarized below.

Table A2-3: Selected Exposure Limits for Beryllium

Route of Exposure	Exposure Limit	Toxicological Basis	Source Agency
Non-Cancer Effects			
Ingestion	2 µg/kg-day	intestinal lesions in dogs	EPA, 1998
Inhalation	0.02 $\mu g/m^3$	beryllium sensitization in human populations	EPA, 1998
Cancer Effects			
Ingestion	N/A[1]		
Inhalation	0.0024 $(\mu g/m^3)^{-1}$	lung cancer in humans	EPA, 1998

1. Not Applicable

A2-4.4 Beryllium References

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A2-5 Toxicological Profile for Cadmium

The health risk of cadmium (Cd) exposure in Ontario soils has been assessed for Port Hope (MOE, 1991). This appendix updates MOE (1999).

Cadmium is a natural element that is usually found as a mineral combined with other elements such as oxygen, chloride, and sulphur. Cadmium forms both organic and inorganic compounds. It is extracted mostly during the production of other metals, and is used in batteries, pigments, metal coatings, and plastics.

A2-5.1 Pharmacokinetics

Following inhalation, the major site of cadmium absorption in humans is the alveoli of the lung. Human data are not available for absorption in the lung. A kinetic respiratory tree model has been developed to predict cadmium particle deposition in the lung (Nordberg et al, 1985). This model suggests that only 5% of the particles that are greater than 10 µm in diameter will be deposited and that about 50% of the particles less than 0.1 µm will be deposited. The respiratory tree model also predicts that 50 to 100% of the cadmium deposited in the alveoli will be absorbed.

The majority of ingested cadmium tends to pass through the gastrointestinal tract without being absorbed and is excreted in the feces. Almost all of the cadmium found in the feces represents cadmium which was not absorbed from the gastrointestinal tract. Absorption of ingested cadmium is influenced by nutritional status, with absorption increased by low intake of calcium, iron, zinc and copper (Nordberg et al., 1985). Absorbed (from the lungs and gastrointestinal tract) cadmium tends to be excreted very slowly and is found equal proportions in the urine and feces. The main target organ for cadmium following ingestion is the kidney. The half-life of cadmium in the human body is very long. An estimated half-life for cadmium in the kidney ranges from 6 to 38 years and the liver from 4 and 19 years (ATSDR, 1998). The placenta may act as a partial barrier to fetal cadmium exposure.

Cadmium is not metabolized, rather it binds to proteins and other molecules. In particular it binds to the protein, albumin in the bloodstream which transports cadmium to the liver. Once cadmium enters the liver it becomes bound to another protein called metallothionein and is released to the bloodstream. The metallothionein bound cadmium is then filtered by the kidney glomerulus and is then reabsorbed by the proximal tubule cells. Lysozymes (strong enzymes) degrade the cadmium-metallothionein complex and cause free cadmium to be released in the kidney. The free cadmium initiates the synthesis of metallothionein in the proximal tubule cells and can also cause damage to the kidneys in excessive amounts.

There is currently not enough information to determine the potential absorption of cadmium via the dermal route of exposure (ATSDR, 1998). Based on the limited information it appears that very little cadmium is absorbed through the skin

A2-5.2 Toxicology

Cadmium and cadmium compounds possess moderately acute toxicity via both ingestion and inhalation. Cadmium is slowly excreted by the body, and therefore bioaccumulates in humans. Chronic cadmium poisoning can be associated with both inhalation and ingestion.

A2-5.2.1 Non-Cancer Effects

Based on studies of cadmium production workers, the route of entry for cadmium with the most immediate health effects is inhalation of fumes or dust. Localized health effects caused by cadmium exposure include irritation to the respiratory tract and to the mucous membrane lining of the inner surface of the eyelid. This is often accompanied by dyspnea (severe difficulty in breathing) and general weakness. Troubled breathing may become more pronounced as pulmonary adema and tracheobronchitis develop. The most common result of acute systemic cadmium exposure is emphysema, but in some instances, mortality may occur. Prolonged exposure may also result in anosmia (loss of sense of smell) and discolouration of the teeth.

Ingestion of high acute doses of cadmium may cause gastrointestinal effects such as nausea, vomiting, and abdominal pain (Nordberg et al, 1973). Cadmium causes kidney damage, particularly to the proximal renal tubules in the early stages and, as the disease progresses, or the dose increases, glomerular damage is also observed. Renal dysfunction has been demonstrated to be a consequence of chronic low level exposure to cadmium (Bernard et al., 1994).

Chronic cadmium exposure coupled with poor nutrition can lead to changes in the way which the kidney metabolizes vitamin D. This can result in painful bone diseases such as osteomalacia and osteoporosis, mainly in women. There is limited data to suggest that cadmium exposures in pregnant women may result in decreased birth weight in their babies.

Cadmium appears to have a relatively low dermal toxicity based on studies that showed that workers who were occupationally exposed to high levels of cadmium dust, did not report any dermal effects. Cadmium does not appear to cause sensitization by repeated dermal contact.

A2-5.2.2 Cancer Effects

Epidemiological studies demonstrate increased incidence of lung cancer in workers exposed to cadmium via the inhalation route, however, the studies did not control for factors such as smoking and simultaneous exposures to other metals so the causal relationship is somewhat controversial. Oral exposure to cadmium has not been associated with cancer in humans or animals.

The United States Environmental Protection Agency has classified cadmium as a probable human carcinogen (Group B2) when inhaled, based on limited human and sufficient animal data (US EPA, 1992). Health Canada has classified cadmium as a Group II carcinogen.

A2-5.2.3 Susceptible Populations

Populations which may be unusually susceptible to cadmium exposure are those with a genetic predisposition to lower inducibility of metallothionein, the enzyme which sequesters cadmium. Dietary deficiencies which lead to depleted levels of calcium or iron in individuals may result in increased absorption of cadmium from the gastrointestinal tract. Infants and children may have increased uptake of cadmium via the gastrointestinal tract and higher concentrations of cadmium in the bone.

A2-5.3 Current Exposure Limits

A2-5.3.1 Oral Exposure Limits

ATSDR (1998) has developed a chronic oral minimum risk level of 0.2 µg/kg-day for cadmium. The chronic MRL is derived from a NOAEL of 2.1 µg/kg-day from a study of cadmium accumulation in the kidneys of Japanese farmers living in an area of Japan with highly elevated cadmium levels. An uncertainty factor of 10 was used to account for variability in the human population.

The United States Environmental Protection Agency has developed oral reference doses for cadmium for food and water. The oral reference dose for food is 1.0 µg/kg-day and for water is 0.5 µg/kg-day (US EPA, 1994). The highest cadmium level in the human kidney which does not produce proteinuria (excretion of low weight molecular proteins into the urine) has been determined to be 200 µg cadmium/g of wet kidney cortex. A toxicokinetic model was used to determine the level of chronic oral exposure that would result in a cadmium kidney concentration of 200 µg cadmium/g of wet kidney cortex. The toxicokinetic model assumes that 0.01% of the body cadmium kidney burden is eliminated daily and that absorption of cadmium from food and water are 2.5% and 5% respectively. A No-Observed-Adverse-Effect Level (NOAEL) for chronic cadmium exposure was determined to be 5.0 and 10 µg/kg-day. An uncertainty factor of 10 to account for human variability was applied to the NOAELs to develop the reference doses for food and water.

JECFA (WHO, 1993) proposed that the total daily intake of cadmium should not exceed 1 µg/kg body weight/ day. This intake was designed to keep the cadmium levels in the renal cortex below 50 µg/g, and assumed an absorption rate for dietary cadmium of 5% and a daily excretion rate of 0.005% of body burden (WHO, 1996).

Health Canada has not determined a tolerable daily intake for cadmium (HC, 1996).

A2-5.3.2 Inhalation Exposure Limits

The US EPA (US EPA, 1998) has developed an inhalation unit risk of 1.8×10^{-3} $(\mu g/m^3)^{-1}$. This unit risk is based on lung and upper respiratory tract cancers in cadmium production workers (Thun et al., 1985). The air concentration at the 10^{-5} lifetime cancer risk level (1-in-100,000) is 0.006 $\mu g/m^3$.

The WHO has an annual guideline value (noncancer) of 0.005 $\mu g/m^3$ (WHO, 2000)

Health Canada has calculated a TC_{05} of 5.1 $\mu g/m^3$. This TC_{05} can be divided by 5000 to obtain a 10^{-5} lifetime cancer risk air concentration of 0.001 $\mu g/m^3$.

A2-5.3.3 Selection of Exposure Limits

The estimates of the carcinogenic potencies of inhaled and ingested cadmium, developed by the US EPA will be used to assess potential human health risks associated with exposure to cadmium at this site. The potency estimates established by the US EPA and the health effects upon which they are based are summarized below.

Table A2-4: Selected Exposure Limits for Cadmium

Route of Exposure	Exposure Limit	Toxicological Basis	Source Agency
Non-Cancer Effects			
Ingestion	1 $\mu g/kg$-day	kidney damage in humans	EPA, 1998, WHO (JECFA), 1993
Inhalation			
Cancer Effects			
Ingestion	N/A[1]		
Inhalation	0.0018 $(\mu g/m^3)^{-1}$	lung cancer in cadmium workers	EPA, 1998

1. Not Applicable

A2-5.4 Cadmium References

ATSDR (Agency for Toxic Substances and Disease Registry). 1998. Toxicological Profile for Cadmium. U.S. Department ofHealth and Human Services - Public Health Service (CDROM version, 2000).

Bernard, A.M., H. Roels, A. Cardenas and R. Lauwerys. 1994. Assessment of urinary protein 1 and transferrin as early markers of cadmium nephrotoxicity. Brit. J. Ind. Med. 47: 559-565.

CEPA (Canadian Environmental Protection Act), 1994. Cadmium and its compounds. Priority substances list assessment report. Government of Canada: Environment Canada, Health Canada. ISBN 0-662-22046-3.

Health Canada. 1996. Health-Based Tolerable Daily Intakes/Concentrations and Tumorigenic Doses/Concentrations for Priority Substances. ISBN 0-662-24858-9.

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World Health Organization (WHO). 2000. Guidelines for air quality. WHO, Geneva

A2-6 Toxicological Profile for Cobalt

The health risk of cobalt (Co) exposure in Ontario soils has been assessed for Port Hope (MOE, 1991) and Port Colborne (MOE, 1998). This appendix updates MOE (1998).

Cobalt exists in nature as a brittle hard metal, closely resembling iron and nickel in appearance. It has two valence states (Co(II) and Co(III)), which form numerous organic and inorganic salts. It is alloyed with iron and nickel to make Alnico. Cobalt is used in Stellite alloys, and stainless steel alloys used in jet and gas turbines. Cobalt salts have been used for centuries for the production of brilliant and permanent blue colours in porcelain, glass, pottery and enamel.

Cobalt is an essential nutrient for humans as it is needed to make vitamin B_{12}. Vitamin B_{12} is a coenzyme in many biological reactions including the production of red blood cells. Cobalt has, therefore, also been used to treat anemia. As cobalt is an essential element, it is found in most body tissues with the highest concentrations occurring in the liver, kidney and bones.

A2-6.1 Pharmacokinetics

Inhaled cobalt particles accumulate in the respiratory tract depending on particle size. From the lungs, cobalt particles either dissolve into the bloodstream or are transferred to the gastrointestinal tract by mucocilliary action and swallowing. Approximately 50% of the cobalt transferred to the gastrointestinal tract is actually absorbed and the rest is eliminated in the feces. About 50 % of the portion of the initial lung burden can remain up to 6 months after exposure (Foster et al, 1989 as cited in ATSDR, 1992).

Cobalt consumed by the oral route of exposure is absorbed by the gastrointestinal tract. The amount of cobalt absorbed ranges from18 to 97% in humans and is dependent upon the dose and type (form) of cobalt as well as the nutritional status of the individuals involved. Cobalt absorption tends to increase in subjects which have iron deficiencies in their diet. Elimination in the feces is the primary excretion method for oral cobalt exposures.

Absorption of cobalt through intact, or unbroken skin does not generally occur (ATSDR, 1992). However, cobalt may be absorbed through broken or injured skin.

A2-6.2 Toxicology

A2-6.2.1 Non-Cancer Effects

Acute effects of exposure to cobalt-containing dust occupationally are typically inflammation of the nasopharynx. Inhalation of cobalt can affect the respiratory system and if sufficient quantities are inhaled (3 μg cobalt/m^3), irritation, wheezing, asthma and pneumonia can result. The occupational exposure levels noted here are approximately 10,000 to 100,000 times the typical outdoor air concentration. Individuals can also develop a sensitivity to cobalt if exposed continually in an occupational setting to concentrations of about 7 μg cobalt/m^3 and subsequent exposures can result

in skin rashes or asthma attacks (ATSDR, 1992).

Oral exposure to cobalt has occurred in humans who consumed beer containing cobalt salts. In the 1960s, cobalt salts were added to beer to improve its foaming qualities. This practise has been discontinued as it led to several deaths amongst heavy beer drinkers (8 to 30 pints per day) who consumed doses ranging from 3 to 10 mg cobalt/per day ("beer drinkers cardiomyopathy"). Less serious effects associated with the consumption of beer containing cobalt compounds included nausea, vomiting and diarrhea. Increased production of red blood cells also occurs in humans after oral exposure to cobalt. Decreased uptake of iodine by the thyroid gland has been observed in humans exposed to short term doses of 1000 µg cobalt/kg-dayay or longer term doses of 540 µg cobalt/kg-dayay (ATSDR, 1992).

Developmental effects were not observed in babies born to mothers who were taking medication containing cobalt to regulate anemia while pregnant (Holly, 1955 as cited in ATSDR, 1992). Reproductive effects were not observed in the people who died after exposure to high cobalt levels in beer. Some effects have been observed in animals (adverse effects on the testes and increased length of the estrous cycle), however, the significance of these effects for humans is not clear as the cobalt doses used in these studies were much higher than those to which humans are usually exposed.

Contact dermatitis has also been consistently reported upon acute dermal exposure occupationally to cobalt compounds.

A2-6.2.2 Cancer Effects

There is insufficient evidence to implicate cobalt or cobalt compounds as human carcinogens. Cobalt has not been shown to cause cancer in humans.

Hamsters exposed cobalt oxide dust did not develop an increased incidence of lung tumours in comparison to the control population. Intramuscular injection of cobalt oxide resulted in the production of tumours in rats but not in mice (Gilman 1962 as cited in ATSDR, 1992). Based on animal data, the International Agency for Research on Cancer has classified cobalt as 2B; possibly carcinogenic for humans.

A2-6.2.3 Susceptible Populations

People who are already sensitized to cobalt may be unusually susceptible because subsequent cobalt exposure may trigger an asthma attack. Cobalt sensitization can be determined by cobalt-specific changes to serum antibodies (IgE and IgA)

A2-6.3 Current Exposure Limits

A2-6.3.1 Oral Exposure Limits

The recommended daily intake of cobalt as vitamin B_{12} is 2 µg / day for adults and 0.3 µg/day for children less than two years old (Food and Drugs Act and Regulations (Canada)).

The USEPA Region III derived an oral R*f*D of 60 µg/kg-dayay for cobalt based on cobalt intake levels in food (USEPA, 2000). This R*f*D was based on the upper range of average intake for children, that is below the levels of cobalt needed to induce polycythemia in both renally compromised patients. However, the current USEPA IRIS list of chemicals does not include cobalt (USEPA, 1998).

A2-6.3.2 Inhalation Exposure Limits

An intermediate minimal risk level (MRL) of 0.03 µg cobalt/m^3 is proposed by the Agency for Toxic Substances and Disease Registry (ATSDR, 1997). This inhalation R*f*D is based on a LOAEL of 110 µg /m^3 (as cobalt sulfate) for squamous metaplasia of the larynx in rats and mice exposed for 13 weeks in the NTP (1991) and Bucher *et al.* (1990) studies. A safety factor of 1000 was applied.

No regulatory dermal exposure limits for cobalt were identified in the literature reviewed for the current assessment.

A2-6.3.3 Selection of Exposure Limits

The estimates of the carcinogenic potencies of inhaled and ingested cobalt, developed by the US EPA will be used to assess potential human health risks associated with exposure to cobalt at this site. The potency estimates established by the US EPA and the health effects upon which they are based are summarized below.

Table A2-5: Selected Exposure Limits for Cobalt

Route of Exposure	Exposure Limit	Toxicological Basis	Source Agency
Non-Cancer Effects			
Ingestion	60 µg/kg-day	effects in renally compromised patients	EPA, Region III, 2000
Inhalation			
Cancer Effects			
Ingestion	N/A[1]		
Inhalation	0.03 µg/m^3	squamous metaplasia in rodent larynx	ATSDR, 1997

1. Not Applicable

A2-6.4 Cobalt References

ATSDR (Agency for Toxic Substances and Disease Registry). 1992. Toxicological Profile for Cobalt. U.S. Department of Health and Human Services - Public Health Service (CDROM version, 2000).

Dabeka, R.W., and A.D. McKensie. 1995. Survey of lead, cadmium, fluoride, nickel, and cobalt in food composites and estimation of dietary intakes of these elements by Canadians in 1986-1988. J.AOAC. Intl. 78(4): 897-909.

MOE. 1998. Assessment of Potential Health Risk of Reported Soil Levels of Nickel, Copper and Cobalt in Port Colborne and Vicinity - May 1997. PIBS 3685e.

MOE & MOL. 1991. Assessment of Human Health Risk of Reported Soil Levels of Metals and Radionuclides in Port Hope. PIBS 1727.

US EPA. 2000. Risk-Based Concentration Table. US Environmental Protection Agency, Region III, Philadelphia, Penn. Available online at http://www.epa.gov/reg3hwmd/risk/riskmenu.htm.

A2-7 Toxicological Profile for Copper

The health risk of copper (Cu) exposure in Ontario soils has been assessed for Port Hope (MOE, 1991) and Port Colborne (MOE, 1998). This appendix updates MOE (1998).

Copper is a natural element that is also an essential nutrient for the human body. It is used as a conductive agent in electrical equipment, reducing agent, catalyst, and as wire material, and can be found in some pesticides.

Copper can be ingested from drinking water or eating certain foods. Another possible route of exposure includes the inhalation of roadway dust containing copper from the use of car brakes. It could also be ingested from foods that have absorbed it from copper cookware. Copper sulphate is used as a pesticide, fungicide and nutritional supplement in animal feed and fertilizer.

Copper is an essential element for humans and is found widely throughout the body. Adverse health effects can be linked to both copper deficiency as well as excessive copper levels. Copper deficiency is demonstrated by anemia, neutropenia and bone abnormalities, but is rarely observed in clinical situations. Copper is considered essential for the development of structural and enzymatic proteins. Enzymes regulating cellular respiration, free radical detoxification, iron metabolism, neurotransmitter function and synthesis of connective tissue contain copper. Regulation (activation and repression) of gene transcription also requires copper. Copper concentrations are regulated in the body by a process called homeostasis (ATSDR, 1990).

Copper regulates the mechanism which controls its intracellular homeostasis. Copper enters the liver where it is reduced and then complexes with glutathione. Metallothionein is the primary protein to which copper binds and these proteins are involved in the detoxification and binding of excess copper. Copper binds to the transcription factor which causes the production of metallothionein. When cellular copper levels are high then copper will bind to the metallothionein transcription factor causing metallothionein production, thereby detoxifying excess copper concentrations. If cellular copper levels are low, it is unlikely that there will be enough copper to bind to the metallothionein transcription factor, thereby limiting the production of metallothionein so that the copper can be used for metabolism (Gollan, 1996 as cited in WHO, 1998).

A2-7.1 Pharmacokinetics

No studies were found which document absorption, distribution or elimination of copper following inhalation exposure.

Absorption of copper occurs primarily through the gastrointestinal tract. Copper absorption is related to the amount of copper in the diet. For example, when adults were administered a low copper diet (780 µg copper per day) 55.6% of the administered copper was absorbed by the gastrointestinal tract as determined by the use of isotopes. For adults who were administered an adequate dose of copper in their diet (1,680 µg copper per day), 36.3% absorption was observed and for adults with a high daily copper intake (7,530 µg copper per day) only 12.4 % absorption was

found. Copper absorption in adults is saturable and the percentage of copper absorbed, decreases as the daily intake of copper increases. Total retention of copper increased with dietary intake and appropriate balance was maintained even at the lowest concentration studied (780 µg copper per day). Copper absorption and metabolism decreases as a result of competition with high levels of other metals such as iron and zinc for binding sites on metallothionein. Molybdenum inhibits copper retention.

Recent studies with an isotopic tracer indicate that infants absorb sufficient copper to meet their growth needs (Eherenkranz, 1989 as cited in WHO, 1998). Infants appear to reduce copper intake at high dietary concentrations by increasing fecal elimination and decreasing absorption.

The liver is the major organ involved in the distribution of copper throughout the body; distribution of copper to other tissues throughout the body occurs through the blood stream. The highest concentrations of copper are found in the brain, kidney, heart, liver and pancreas. Ceruloplasmin (a protein which can bind 6 to 8 Cu(II) atoms) and serum albumin appear to be the major carriers of copper through the bloodstream.

Bile is the major elimination pathway for liver copper as it accounts for approximately 80% of the copper leaving the liver. Pregnancy is associated with increased copper retention likely due to decreased biliary excretion resulting from the hormonal changes which typically occur. Urinary excretion and sweating are minor contributors to copper removal.

The use of topical medications containing copper compounds can increase dermal absorption of copper (Eldad, 1995 as cited in WHO, 1998). Components of topical medication such as salicylic acid or phenylbutazone facilitate the transport of copper through the skin.

A2-7.2 Toxicology

A2-7.2.1 Non-Cancer Effects

Inhalation exposure information is limited to studies on factory workers who have been exposed to significantly higher copper air concentrations than the general public. Copper dust is considered a respiratory irritant as factory workers experienced irritation of the mucosal membranes of the mouth, nose and eyes. Metal fume fever has also been observed in workers exposed to high concentrations of fine copper dust in air. Gastrointestinal effects such as nausea, anorexia and occasionally diarrhea were also experienced by factory workers and it is thought that the gastrointestinal effects are primarily due to swallowing a portion of the airborne copper (i.e., would be classified as an oral exposure).

Copper is rarely toxic unless very large amounts are ingested. The available toxicity data associated with oral consumption of copper are limited to ingestion of water with very high copper concentrations or suicide attempts involving copper sulphate. Chronic exposure to drinking water containing (dose approximately 60 µg copper/kg-day - 4,200 µ g copper/day for a 70-kg adult) resulted in nausea, vomiting and abdominal pain shortly after consumption of the water. The gastrointestinal difficulties stopped after an alternate water supply was found for the affected persons.

Chronic copper poisoning is very rare, since the capacity for healthy human livers to excrete copper is considerable. Any reports of chronic copper poisoning that do exist involve patients with liver disease.

Developmental effects have not been observed in children of mothers with Wilson's Disease (a metabolic disorder which causes accumulation of copper in the liver) or healthy humans. Developmental toxicity has been found in mice, mink and hamsters who were fed a high copper diet or injected with copper. Reproductive effects have not been observed in human populations exposed to high copper levels. Copper containing intrauterine devices are used as a method of birth control and animal studies have shown that the copper wires contained within these devices are the contraceptive agent.

Dermal exposure to copper can result in allergic contact dermatitis.

A2-7.2.2 Cancer Effects

The United States Environmental Protection Agency has classified copper and copper compounds in Group D which indicates that they are substances for which inadequate data are available to make a carcinogenicity assessment. Specifically, for copper and copper compounds there are no human carcinogenicity data, animal bioassay data is inadequate and mutagenicity tests are equivocal (US EPA, 2000)

A2-7.2.3 Susceptible Populations

Infants and children under 1 year old are unusually susceptible copper toxicity because they have not developed the homeostatic mechanism to remove copper from the body. Wilson's Disease is a genetic disorder associated with impaired transport of copper from the liver to the bile, thereby resulting in increased copper concentrations in the liver as they are not able to maintain homeostasis. Another genetic condition which increases the susceptibility to copper toxicity is a deficiency in the enzyme glucose-6-phosphate dehydrogenase. Individuals with liver disease are also susceptible to copper toxicity because of the critical role the liver plays in eliminating copper from the body.

A2-7.3 Current Exposure Limits

A2-7.3.1 Oral Exposure Limits

As copper is considered an essential element for humans there are two types of exposure limits that are considered (a) the minimal daily intake so that a person will not be suffer from copper deficiency and (b) the maximal permissible daily intakes so that a person will not suffer from copper toxicity.

The World Health Organization (WHO, 1998) has determined the minimal daily copper intake for adults to be 20 μg copper /kg-day which is equivalent to 1,400 μg copper per day for the average 70 kg adult. For children, the World Health Organization concluded that the minimal daily copper

intake should be 50 µg copper/kg-day (equivalent to 750 µg copper per day for a 15 kg child). The minimal daily copper intake was determined as the amount of copper needed for a child or adult to function properly while accounting for variables such as differences in copper absorption, retention and storage.

The Recommended Dietary Allowance (RDA) for US adults is 900 µg copper/day or about 13 µg/kg-day (IOM, 2001). This RDA is a combination of indicators, including plasma copper and ceruloplasmin concentrations, erythrocyte superoxide dismutase activity and platelet copper concentration in controlled human depletion/repletion studies.

The US Reference Daily Intake (a term which replaces "US RDA") for copper is 2000 µg/day or about 30 µg/ kg/day for adults (US FDA Consumer online magazine).

The tolerable upper intake level for US adults is 10,000 µg/day or about 140 µg / kg /day, and is based on protection from liver damage (IOM, 2001).

A2-7.3.2 Inhalation Exposure Limits

A chronic non-cancer Reference Exposure Level (REL) of 2.4 µg/m^3 is listed for copper compounds in the California Air Pollution Control Officers Association Air Toxics "Hot Spots" Program, Revised 1992 Risk Assessment Guidelines. This REL are based on respiratory effects (CAPCOA, 1993). The United States Environmental Protection Agency (U.S. EPA) has not established a Reference Concentration (RfC) for copper compounds (U.S. EPA, 1994a).

A2-7.3.3 Selection of Exposure Limits

The estimates of the carcinogenic potencies of inhaled and ingested copper, developed by the US EPA will be used to assess potential human health risks associated with exposure to copper at this site. The potency estimates established by the US EPA and the health effects upon which they are based are summarized below.

Table A2-6: Selected Exposure Limits for Copper

Route of Exposure	Exposure Limit	Toxicological Basis	Source Agency
Non-Cancer Effects			
Ingestion	140 µg/kg-day	liver damage	IOM, 2001
Inhalation			
Cancer Effects			
Ingestion	N/A[1]		
Inhalation	2.4 µg/m^3	chronic reference exposure limit - respiratory	California, 1998;

1. Not Applicable

A2-7.4 Copper References

ATSDR (Agency for Toxic Substances and Disease Registry). 1990. Toxicological Profile for Copper. U.S. Department of Health and Human Services - Public Health Service (CDROM version, 2000).

MOE. 1998. Assessment of Potential Health Risk of Reported Soil Levels of Nickel, Copper and Cobalt in Port Colborne and Vicinity - May 1997. PIBS 3685e.

California Air Resources Board. 1998. List of Toxic Air Contaminants - Compound Summary Table. On-line at http://www.arb.ca.gov/toxics/tac/tac.htm

Canadian Council of Ministers of the Environment (CCME). 1997. Canadian Soil Quality Guidelines for Copper. CCME Subcommittee on Environmental Quality Criteria for Contaminated Sites. ISBN 0-662-25520-8.

MOE & MOL. 1991. Assessment of Human Health Risk of Reported Soil Levels of Metals and Radionuclides in Port Hope. PIBS 1727.

Institute of Medicine (Food and Nutrition Board) (IOM). 2001. Dietary Reference Intakes for Vitamina A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc. National Academy Press, Washington, D.C.

US EPA. 2000. Integrated Risk Information System (IRIS). Copper. US Environmental Protection Agency. Online at http://www.epa.gov/iris/index.html.

World Health Organization (WHO). 1998. Copper. Guidelines for drinking-water quality, 2nd ed. Addendum to Vol. 2 Health criteria and other supporting information. WHO, Geneva. Pp. 31-46.

A2-8 Toxicological Profile for Lead

The health risks of lead have been assessed in detail for several Ontario communities (MOE, 1991; MOEE, 1994). This appendix offers supplemental information to section 5.8 of the main report (Part B).

Lead is a bluish-white lustrous metal. It is very soft, highly malleable, ductile, and a relatively poor conductor of electricity. It is very resistant to corrosion but tarnishes upon exposure to air. Lead pipes bearing the insignia of Roman emperors, used as drains from the baths, are still in service. Alloys include pewter and solder. Tetraethyl lead was used in some grades of petrol (gasoline).

A2-8.1 Pharmacokinetics

The absorption, distribution, metabolism, and elimination of lead has been extensively studied in both animals and humans. Available data can be used to quantify the uptake and disposition of lead in the human body for various populations of children and adults. Lead absorption is influenced by the route of exposure, chemical speciation, the physicochemical characteristics of the lead and exposure medium, and the age and physiological states of the exposed individual (e.g., fasting, nutritional calcium and iron status).

The primary sites for inorganic lead absorption are the gastrointestinal and respiratory tracts. The bioavailability of ingested soluble lead in adults may vary from less than 10% when ingested with a meal to 60–80% when ingested after a fast. Immediately following absorption, lead is widely distributed to blood plasma and soft tissues, then it redistributes and accumulates in bone (ATSDR. 1993).

Bone lead accounts for approximately 73% of the total body burden in children, increasing to 94% in adults due to changes in bone turnover rates with age. Transplacental transfer of lead has been demonstrated based on measurements of lead in umbilical cord blood in humans, as well as tissue concentrations in offspring of mice.

Lead that is not retained in the body is excreted principally by the kidney as salts or through biliary clearance into the gastrointestinal tract in the form of organometallic conjugates. Excretion rates measured in infants, children, and adults are highly variable, although available data suggest that the fraction of absorbed lead that is retained in humans decreases with age (ATSDR. 1993)

Dermal absorption of lead compounds is less significant than either oral or inhalation routes of exposure (ATSDR. 1993). Information on the dermal absorption of lead containing compounds is limited to a single study which applied a lotion containing lead acetate to the forearms of male volunteers, reported a dermal absorption rate of approximately 0.06% over a 12 hour period (ATSDR. 1993).

A2-8.2 Toxicology

A2-8.2.1 Non-Cancer Effects

The potential for lead to impair neurobehavioural development in children is the subject of much concern. Acute inhalation and oral exposures to lead often results in central nervous system effects including; dullness, restlessness, irritability, poor attention span, headaches, muscle tremors, hallucination and loss of memory (Health Canada 1992). Encephalopathy has been reported at very high lead exposure levels (100 μg lead/deciliter of blood in adults and 80 μg/dL in children) (Health Canada 1992).

Chronic exposure to elevated levels of lead can result in a number of nervous system effects. Tiredness, sleeplessness, irritability, headaches, joint pain and gastrointestinal symptoms have all been reported (Health Canada, 1992). In adults, these effects are seen at blood lead levels of 50 - 80 μg/dL. Occupationally exposed persons have been found to suffer from muscle weakness, mood disruptions, and peripheral neuropathy when blood lead levels reached 40 - 60 μg/dL. At levels of 30 - 50 μg/dL, significant reductions in nerve conductive velocities were also reported (Health Canada, 1992). Renal disease has also been reported, but nephropathy has not been detected in adults of children whose blood lead levels were below 40 μg/dL (Health Canada, 1992).

There is substantial human evidence in both adults and children which demonstrates that both the central and peripheral nervous system are the primary targets of lead toxicity. Sub-Encephalopathy, neurological and behavioral effects in adults and electrophysiological evidence of nervous system damage in children have been reported at blood lead levels as low as 30 μg/dL (Health Canada, 1992). A number of epidemiological studies have examined the effects of lead exposure in young children. The studies were able to demonstrate no clear threshold below which the detrimental effects of lead on child neurological development does not occur (Health Canada, 1992).

Epidemiological studies of occupationally exposed adults were not able to demonstrate an increase in cancers among an exposed cohort compared to control. The International Agency for Research on Cancer (IARC), considers the overall evidence of lead carcinogenicity in humans to be inadequate. Animal studies have reported renal tumors in rats exposed to 1000 ppm lead salts in the diet. While exposures to lead acetate, subacetate and phosphate salts produced renal tumors in rats, equivalent exposures to other lead salts did not result in the production of renal tumors (Health Canada, 1992). Health Canada has classified lead as a Group IIIB (possibly carcinogenic to humans) compound based on a lack of adequate human data and limited evidence of carcinogenicity in animals.

Epidemiological studies have indicated that non-cancer neurological effects may occur at very low exposure levels. Therefore, an exposure level based on these effects will provide against the possible carcinogenic effects of lead. Health Canada (1996) recommended a provisional tolerable daily intake (PTDI) for lead of 3.57 g/kg-dayay. This value was based on technical reports from annual meetings of the Joint FAO/WHO Expert Committee on Food Additives (JEFCA), and epidemiological studies associating lead exposure with neurological effects in infants and children. The WHO value was established to prevent increases in blood lead levels in children. Studies with young children have shown that daily exposures to lead in the 3 -4 μg/kg-day range do not alter the blood lead level in the study children. Intakes at or above 5 μg/kg-day resulted in significant increases in blood lead levels.

A2-8.2.2 Cancer Effects

The USEPA (US EPA,1998) has classified lead as a probable human carcinogen based on sufficient animal evidence. However, the Carcinogen Assessment Group (USEPA, 1998) did not recommend derivation of a quantitative estimate of oral carcinogenic risk, due to a lack of understanding pertaining to the toxicological and pharmacokinetic characteristics of lead. In addition, the neurobehavioural effects of lead in children were considered to be the most relevant endpoint in determining an exposure limit.

A2-8.2.3 Susceptible Populations

There is a very large database which documents the effects of acute and chronic lead exposure in adults and children. Extensive summaries of the human health effects of lead are available from a number of sources including Health Canada, the US EPA IRIS database and the ATSDR. These reviews show that infants, young children up to the age of 6 and pregnant women (developing foetuses) are the most susceptible (Health Canada 1992).

A2-8.3 Current Exposure Limits
A2-8.3.1 Oral and Inhalation Exposure Limits

Health Canada (1996) recommended a provisional tolerable daily intake (PTDI) for lead of 3.57 g/kg-dayay. This value was based on technical reports from annual meetings of the Joint FAO/WHO Expert Committee on Food Additives (JEFCA), and epidemiological studies associating lead exposure with neurological effects in infants and children.

The Ontario Ministry of the Environment and Energy recommended an IOC_{pop} (intake of concern for populations) of 1.85 μg/kg-dayay which incorporated the population-based significance of the health effects and attempted to minimize the predicted number of children with individual blood lead levels of concern (MOE, 1994). Subclinical neurobehavioural and developmental effects were the critical effects appearing at the lowest levels of exposure (MOE, 1994). The IOC_{pop} was based on an LOAEL in infants and young children of 10 μg/dL, converted to an intake, with an applied uncertainty factor of 2 for the use of an LOAEL (MOE, 1994). Because the IOC_{pop} was intended for the entire population and independent of route of exposure, 1.85 μg/kg-dayay was adopted for both oral and inhalation exposure limits for the current assessment.

A2-8.3.3 Selection of Exposure Limits

The exposure limits used to assess the potential risks associated with ingestion and inhalation exposures to nickel are summarized in Table A2-7.

Table A2-7: Selected Exposure Limits for Lead

Route of Exposure	Exposure Limit	Toxicological Basis	Source Agency
Non-Cancer Effects			
Ingestion	1.85 µg/kg-day	blood lead level in young chidren	MOE, 1994
Inhalation	1.85 µg/kg-day	blood lead level in young chidren	MOE, 1994
Cancer Effects			
Ingestion	N/A[1]		
Inhalation	N/A[1]		

1. Not Applicable

A2-8.4 Lead References

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US EPA (2001)Identification of Dangerous Levels of Lead: Final Rule. Federal Register 66:1205-1240.

A2-9 Toxicological Profile for Nickel

The health risk of nickel (Ni) exposure in Ontario soils has been assessed for Port Hope (MOE, 1991) and Port Colborne (MOE, 1998). This appendix updates MOE (1998).

Pure nickel is a hard, silvery-white metal, which has properties that make it very desirable for combining with other metals to form mixtures called alloys. Some of the metals that nickel can be alloyed with are iron, copper, chromium, and zinc. These alloys are used in making metal coins and jewelry and in industry formaking items such as valves and heat exchangers. Most nickel is used to make stainless steel. Compounds of nickel combined with many other elements, including chlorine, sulfur, and oxygen, exist. Many of these compounds dissolve fairly easily in water and have a characteristic green color. Nickel and its compounds have no characteristic odor or taste. Nickel compounds are used for nickelplating, to color ceramics, to make some batteries, and as substances known as catalysts that increase the rate of chemical reactions (ATSDR, 1997).

The physiological role of nickel in animals and humans has not yet been determined. It is believed, based on plants and microorganisms, that nickel is involved as a cofactor in metalloenzymes/proteins or as a cofactor which facilitates iron absorption in the intestine (Nielsen, 1985). Nickel may also affect endocrine function regulating prolactin levels. Nickel deficiency has not been observed in humans, but has been induced in animals, indicating that nickel is an essential element for animals (Schnegg and Kirchgessner, 1975).

An important issue relating to nickel toxicity is its speciation. Its form (metallic, salt, oxide, etc.) and solubility strongly influence its toxicology. The solubility (in water) of different nickel compounds ranges from the highly soluble nickel salts (nickel chloride - 642 g/L; nickel sulphate - 293 g/L) down to the insoluble nickel oxide (1.1 mg/L) and the sparingly soluble nickel subsulphide (517 mg/L)(ATSDR, 1997). The predominant nickel species in Rodney Street soils is the relatively insoluble nickel oxide (Results section of Part A).

The toxicity of nickel can be classified into four separate categories: (1) noncancer respiratory and other disorders , due to the inhalation or ingestion of nickel compounds; (2) cancer, due to inhalation of nickel compounds; (3) allergy, a hypersensitivity to nickel manifested by contact dermatitis; and (4) iatrogenic poisoning which may have occurred in the past in patients undergoing hemodialysis, corrosion of stainless steel prostheses, and nickel-contaminated medication or medication such as disulfiram that caused increased nickel concentration in the blood(not discussed).

A2-9.1 Pharmacokinetics
A2-9.1.1 Inhalation Exposure

Following inhalation exposure, nickel may accumulate in the lungs depending on the size of the particle inhaled. Larger particles (5-30 μm) tend to accumulate in the upper respiratory tract while smaller particles are deposited in the lower respiratory system. Absorption of nickel compounds deposited in the lung into the blood stream depends upon their form and solubility. Soluble nickel compounds such as nickel chloride and nickel sulphate are absorbed readily (up to

100%) from the respiratory tract while almost none of the less soluble nickel compounds such as nickel oxide and nickel subsulphide (as demonstrated by urinary nickel levels in exposed workers). Inhaled nickel that is absorbed is excreted through the urine. Studies conducted on nickel workers show that nickel urinary excretion increased towards the end of the shift and also towards the end of the work week, indicating that one fraction is removed quickly, but that there was also a fraction which was removed more slowly (Ghezzi *et al.*, 1989, Tola *et al.*, 1979; as cited in TERA, 1999). No reliable estimates are, however, found in the literature for retention and uptake of nickel from nickel oxide inhalation exposure in humans.

Occupational exposure to nickel results in higher nickel lung burdens than the general population. Workers exposed to insoluble forms of nickel (such as nickel oxide and nickel sulphide) have higher nickel levels in the nasal mucosa than those workers exposed to more soluble forms of nickel (this may be related to larger inhalable dust particles being trapped in the upper respiratory tract) . Less soluble nickel compounds, therefore, appear to remain in the nasal passage following inhalation exposure. Serum nickel levels are higher in workers exposed to soluble nickel compounds in comparison to those exposed to insoluble nickel compounds (Torjussen and Andersen, 1979, as cited in ATSDR, 1997). Nickel sensitized individuals had similar nickel levels in blood, urine and hair relative to nonsensitive individuals (Spruit and Bongaarts, 1977, as cited in ATSDR, 1997).

Pulmonary exposure to green nickel oxide in rats resulted in nickel excretion in the feces, but not in the urine, indicating that the primary removal mechanism of nickel oxide involved clearance from the lungs rather than by dissolution-absorption processes (Benson et al, 1994 as cited in ATSDR, 1997). The observed excretion could also reflect mucociliary clearance (being brought up in mucus and then being swallowed), in addition to macrophage clearance. Benson et al. (1994) also found that nickel subsulfide is cleared relatively rapidly (half-life of 4 days) from the lungs of rats. They concluded that nickel subsulfide is relatively insoluble in water, but dissolves rapidly in lung fluid.

A2-9.1.2 Oral Exposure

Studies examining the absorption of nickel by humans found that nickel sulphate was 40 times more bioavailable if administered in water than in food (Sunderman, 1989). The bioavailability of nickel also increased when administered in a soft drink, but not when given in milk, coffee, tea or orange juice. (Solomons et al, 1982) Serum nickel levels were found to be elevated in subjects who had fasted prior to the administration of nickel in drinking water, but this was not the case for those who were administered nickel in food. Food tends to decrease the bioavailability of nickel. Some nickel sensitive individuals were found to have decreasing nickel serum concentrations and increasing nickel urinary concentrations with increased administered nickel concentrations (Santucci, 1994). This may be an indication that some nickel sensitive individuals can decrease nickel absorption in response to increased nickel intake. In non-occupationally exposed people, nickel concentrations tend to be highest in lungs, thyroid and adrenal glands, kidney, heart and liver (Rezuke et al., 1987, as cited in ATSDR, 1997). The total amount of nickel estimated to be present in the human body is about 6 mg for a 70-kg adult (Sumino et al., 1975, as cited in ATSDR, 1997).

Quantitative absorption data for unspecified forms of soluble nickel are as follows: 1-27% of

ingested nickel is absorbed (depending on whether food is consumed); approximately 1-6% of nickel administered with food or during a meal is absorbed; 12-27% of nickel absorbed after a fast (data from Diamond et al., 1998, as cited in *TERA*, 1999).

Nickel metabolism occurs via a series of nickel exchange reactions (Sarkar, 1984, as cited in ATSDR, 1997). In human blood, nickel binds to a blood protein called albumin. Nickel competes with copper for a binding site on the albumin (Hendel and Sunderman, 1972, as cited in ATSDR, 1997). Nickel is then transferred from the albumin to L-histidine, an amino acid. The nickel-histidine complex has a low molecular weight and can easily cross biological membranes (Sarker, 1984, as cited in ATSDR, 1997). Nickel is also tightly bound to a nickeloplasmin in human blood which is not available for exchange and hence not transported across biological membranes (Sunderman, 1986, as cited in ATSDR, 1997).

Most ingested nickel is excreted via feces, although the nickel absorbed by the gastrointestinal tract is excreted in the urine. In comparison studies of nickel doses administered with food or water, 26% of the dose given in water was eliminated in the urine and 76% in the feces by the fourth day following administration (Sunderman et al, 1989). In contrast, 2% of the nickel dose administered in food was eliminated in the urine and 102% was eliminated in the feces during the same time period. Nickel can also be eliminated through hair, sweat, milk and skin.

No reliable estimates are, however, found in the literature for retention and uptake of nickel from nickel oxide ingestion exposure.

A2-9.1.3 Dermal Exposure

Studies of the dermal uptake of nickel in humans have been summarized in Appendix 7.

A2-9.2 Toxicology

A2-9.2.1 Inhalation Exposure

The only data available for chronic nickel inhalation exposure for humans is limited to occupational data. One of the limitations associated with the epidemiological data available is that the workers were exposed to several different forms of nickel as well as other metals and irritant gases at the same time, so frequently the observed effects can not be attributed to a particular type of nickel. Other lifestyle factors, such as smoking, which affect disease outcomes are also not always available, thereby limiting the conclusions that can be drawn.

One death has been reported as the result of exposure to very high metallic nickel concentrations (382 mg/m^3) of a small particle size (Sunderman, 1993, as cited in ATSDR, 1997). Workers who were chronically exposed to nickel oxide or metallic nickel at concentrations greater than 0.04 mg/m^3 had a greater incidence of death from respiratory disease (Cornell and Landis, 1984, Polednak, 1981; as cited in ATSDR, 1997). Other respiratory effects found included chronic bronchitis, emphysema, and reduced vital capacity. These workers were also exposed to other metals, so it can not be concluded that nickel is the sole causative agent of the effects observed.

Asthma from primary irritation and as the result of dermal sensitization has also been documented amongst nickel workers (Dolovich et al., 1984, Novey et al., 1983, Shirakawa et al., 1990; as cited in ATSDR, 1997). Increased incidence of cardiovascular-related deaths has not been found in nickel workers.

Nickel refinery workers with elevated urinary nickel concentrations also showed a significant increase in urinary β_2-microglobulin levels, which is indicative of tubular dysfunction in the kidneys (ATSDR, 1997). However, marked differences are seen between the results using single urine samples ("spot samples"), and sampling conducted over a 24-hour period *(TERA*, 1999). Although, male and female workers were exposed to the same average nickel (nickel chloride and nickel sulphide) air concentrations, the women had twice the nickel urinary concentrations of the men (Sunderman and Horak, 1981, as cited in ATSDR, 1997). A study of nickel production workers has found significant increases in levels of immunoglobulin G (IgG), IgA, and IgM as well as a significant decrease in IgE. Serum proteins involved in cell-mediated immunity also increased, suggesting stimulation of the immune system by nickel (Bencko et al., 1983, 1986; as cited in ATSDR, 1997). The *TERA* (1999) report concluded that "the overall epidemiological database regarding potential kidney effects of inhalation exposure to soluble nickel is weak. However, the available data do provide suggestive evidence that the kidney can be affected under exposure conditions below those causing acute toxicity."

Studies show that pregnant female workers at a nickel refining plant in the Kola region in Russia had a 15.9% increase in spontaneous abortions in comparison with a control population of pregnant female construction workers (who were not occupationally exposed to nickel) who had a spontaneous abortion rate of 8.5% (Chashschin et al, 1994). The Russian metal refinery workers were exposed to nickel sulphate concentrations of approximately 0.08 to 0.196 mg nickel/m^3 and corresponding urinary nickel concentrations were 3.2 to 22.6 μg/L. Nickel urinary concentrations in persons not occupationally exposed range from <0.1 to 13.3 μg/L. Heavy lifting and heat stress are also associated with nickel refining. A preliminary study of pregnant Russian nickel refinery workers also indicated that babies born to these women had a 16.9% increase in development effects (primarily cardiovascular and musculoskeletal defects) relative to the children of construction workers who had a 5.8% increase in developmental effects. It is not clear whether the fact that the Russian workers also were exposed to heavy lifting and heat stress, could also be factors contributing to the observed abortions. No indications of fetal toxicity (birth weight of first child) in the general population in nickel smelter cities in the Kola region in Russia (Nikel and Zapoljarnij) were found in a large comparative study of pollution and health in the Norwegian-Russian border area, but further studies are in progress (Smith-Sivertsen et al, 1997; Odland, 1999).

A significant increase of gaps in the chromosomes was found in white blood cells of nickel workers who were exposed to nickel monosulfide and nickel subsulfide. Breakage or exchange of the chromosomes was not observed. The study did not find any correlation between the incidence of the chromosome gaps, blood nickel concentration, duration of nickel exposure or age of workers (Waksvik and Boysen, 1982, as cited in ATSDR, 1997).

A2-9.2.2 Oral Exposure

One death has been reported due to the accidental consumption of an extremely high nickel sulphate concentration (570 mg nickel/kg) (Daldrup et al., 1983, as cited in ATSDR, 1997). Gastrointestinal effects were reported in a incident were workers drank water from a fountain containing nickel sulphate and nickel chloride (Sunderman, 1988). Exposure doses ranged from 7.1 to 35.7 mg nickel/kg. Symptoms included nausea, abdominal pain, vomiting and diarrhea. Neurological effects were also observed in the affected workers.

Oral lethality tests of rats indicated that soluble nickel compounds were more toxic than insoluble nickel compounds. An oral lethal dose for 50% of the population (LD_{50}) for nickel sulphate in female rats was reported to be 39 mg/kg while oral LD_{50} values for insoluble nickel compounds were >3,930 and >3,665 mg/kg for nickel oxide and nickel subsulfide, respectively (Mastromatteo, 1986).

Decreased body weight has been observed in rats and mice given nickel chloride and nickel sulphate in drinking water (Schroeder et al., 1974). Ambrose *et al.* (1976) reported data on rats and dogs exposed for 2 years to nickel sulphate in the diet at 100, 1,000, and 2,500 ppm Noncancer effects included decreased growth in dogs (mid and high doses) and rats (high dose), alterations in blood and urinary chemistry in high-dose dogs, and changes in relative organ weights for mid and high dose female rats (heart and liver) and high dose dogs (kidney and liver). The NOAEL was estimated to be 5,000 μg Ni/kg-dayay, based on the noncancer changes in the rat.

A 3-generation study, carried out by Ambrose *et al.* (1976), noted a higher incidence of stillborns in the first generation of albino rats fed 250, 500, or 1,000 ppm nickel in their diet (nickel sulphate) and depressed body weights of weanlings on the 1,000 ppm diet in all generations. A higher incidence of stillborns was not observed in subsequent generations (Ambrose *et al.*, 1976).

A2-9.2.3 Cancer Effects

Extensive reviews of the toxicology of nickel and nickel compounds, including animal carcinogenicity and human epidemiological data, have been published (IARC, 1990, Doll *et al.*, 1990). The studies reviewed included human exposures associated with nickel mining, smelting, refining and high nickel alloy manufacture. The reviews also indicated that different classes of nickel compounds have different carcinogenic potencies. More recently, the human and animal toxicology of soluble nickel salts is under review (*TERA*, 1999).

The epidemiological studies reviewed by IARC (1990) and Doll *et al.* (1990) have several limitations. The principal limitation was the lack of data related to concentrations of nickel in air within the facilities that were studied. Consequently, it was not possible to establish dose-response relationships for specific nickel species. Doll *et al.* (1990) noted that the conclusions of many of the epidemiological studies (with respect to lung tumours) were confounded by a lack of information about the smoking habits of the workers. It should be noted that several epidemiology studies (including updates of those in the Doll report) have been published since the completion of the Doll report *(TERA*, 1999).

Four studies were used in the U.S. EPA determination of the inhalation unit risk associated

with nickel refinery dust (US EPA, 2001). A cohort of employees of a nickel refinery in West Virginia who experienced a minimum 1 year exposure to nickel refinery dusts (containing nickel subsulphide, sulphate and oxide or only nickel oxide) did not show an increased incidence of lung cancer above expected rates (Enterline and Marsh, 1982). Chovil *et al.* (1981) studied a cohort of nickel refinery workers in Ontario, and observed a dose-related trend for the relationship between weighted exposure in years to the incidence of lung cancer. Similarly, a cohort of Welsh nickel refinery workers had elevated risks of cancer compared to the national average. Increased rates of nasal cancer were observed in men employed prior to 1920, while this rate was less than the national average for those starting work between 1920 and 1925, and equaled the expected value for those employed after 1925 (Doll *et al.*, 1977). A significantly increased lung cancer-related mortality was observed in employees starting prior to 1925 but not in those starting between the years 1930 to 1944. Magnus *et al.* (1982) conducted a study of men employed at a nickel refinery in Norway, and reported an elevated occurrence of respiratory cancer for nickel- exposed workers compared to expected values, and for workers involved in nickel processing steps compared to non-processing employees.

Numerous carcinogenicity experiments have been conducted with nickel compounds, administered *via* injection, inhalation or ingestion. Recent chronic inhalation studies have clearly indicated that different nickel compounds have different carcinogenic potentials and different animal species show different carcinogenic responses to various nickel compounds (NTP, 1996a,b,c).

Inhalation studies of the effects of nickel oxide concentrations of up to 42mg/m^3 on hamsters for a lifetime did not show nickel-induced carcinogenicity (Wehner et al, 1975 as cited in CEPA, 1994) However, rats exposed to 5 or 15 mg or nickel oxide via intratracheal instillation, demonstrated an increase in lung tumours (Pott et al, 1987 as cited in CEPA, 1994). Nickel oxide compounds also caused an increased incidence of tumours at the site of injection in various experimental animals (IARC, 1990)

A number of inhalation studies of nickel carcinogenesis in rats and mice have yielded positive results. Ottolenghi *et al.* (1974) exposed Fischer 344 rats to 0.97 mg nickel sulphide/m^3 for 78 weeks. An increased incidence of lung tumours was observed during treatment and during a 30-week observation period. Sunderman *et al.* (1957, 1959) also observed increased incidences of lung tumours in rats exposed to nickel carbonyl for up to 52 weeks.

The most recent chronic inhalation studies included up to 2-year inhalation exposures to nickel subsulphide, nickel sulphate hexahydrate and nickel oxide (NTP, 1996a,b,c).

In the nickel subsulphide inhalation study, rats were treated with 0, 0.11, or 0.73 mg Ni/m^3 and mice with 0, 0.44 or 0.88 mg Ni/m^3, 6 hours/day, 5 days/week for 104 weeks. NTP concluded that there was an increased incidence of alveolar/bronchiolar adenoma or carcinoma or squamous cell carcinoma in male and female rats, benign or malignant pheochromocytoma in males and benign pheochromocytoma in female rats. NTP concluded that there was no evidence of carcinogenic activity in mice and clear evidence of carcinogenic activity in male and female rats (NTP, 1996a).

In the nickel sulphate hexahydrate study, rats were exposed by inhalation to 0, 0.03, 0.06 or 0.11 mg Ni/m^3 for 104 weeks, in the form of a nickel sulphate hexahydrate aerosol. NTP concluded that there was no evidence of carcinogenic activity (NTP, 1996b).

In the same nickel sulphate hexahydrate study, mice were treated with 0, 0.06, 0.11 or 0.22 mg Ni/m^3 according to the same protocol used for the rats. NTP concluded that there was no evidence of carcinogenic activity (NTP, 1996b).

In the nickel oxide inhalation study, rats were treated with 0, 0.5, 1.0, or 2.0 mg Ni/m^3 and mice with 0, 1.0, 2.0, or 3.9 mg Ni/m^3 for 104 weeks. NTP concluded that there was some evidence of an increased incidence of alveolar/bronchiolar adenoma or carcinoma or squamous cell carcinoma, and benign or malignant pheochromocytoma in rats. NTP concluded that there was no evidence of carcinogenic activity in male mice but equivocal evidence of alveolar/bronchiolar adenoma or carcinoma in female mice (NTP, 1996c).

Increased tumourigenesis in mice, rats and dogs has not been associated with nickel compounds ingested in the diet or in drinking water (Schroeder *et al.* ,1964, Schroeder and Mitchener, 1975, Ambrose *et al.*, 1976).

Intrarenal injection of nickel subsulphide was reported to result in an increased incidence of renal tumours in male Fischer 344/NC rats (Higinbotham *et al.*, 1992). Intrarenal administration of nickel subsulphide to male Fischer 344 rats was associated with an increase in kidney tumours (Sunderman *et al.*, 1990). Nickel acetate was reported to induce a significant increase in lung tumours in rats following a series of intraperitoneal injections (Stoner *et al.*, 1976).

A2-9.2.4 Contact Dermatitis

Nickel dermatitis is the most prevalent effect of nickel and occurs in nickel-sensitized individuals. Nickel sensitization results from extensive contact with nickel-containing material such as jewelry, coins, dental braces, stainless steel etc. Contact dermatitis may also result from occupational exposure (Liden, 1994). Once an individual has been sensitized to nickel, subsequent exposure (inhalation, ingestion, or dermal contact) to low levels of nickel may cause a reaction (Keczkes et al., 1982). Asthma may occur in a small number of sensitized individuals (Dolovich et al., 1984, Novey et al., 1983, Shirakawa et al., 1990; as cited in ATSDR, 1997). However, continued oral exposure to nickel has also been shown to desensitize some individuals and prevent sensitization in other cases.

The issue of contact dermatitis following ingestion of nickel-containing food items has been reviewed (US FDA, 1993). In studies where nickel (mainly in a soluble form such as the sulphate) was administered to human subjects with chronic nickel dermatitis or eczema, single doses of 2,500 µg to 5,600 µg nickel produced aggravated reactions (Cronin et al., 1980; Kaaber et al., 1978; Gawkroder et al., 1986; Veien et al., 1983). One double-blind study showed that a single 2,500 g dose of orally administered nickel was sufficient to aggravate the chronic nickel dermatitis in 17 of the 28 patients tested (Veien et al., 1983). Other, less reliable studies suggest that as little as 600 g or 1,250 g of ingested nickel may exacerbate the skin conditions in patients with long-standing (10-17 years) nickel hypersensitivity. In one double-blind study (Jordan and King, 1979), one of the 10 nickel hypersensitive patients tested consistently reacted to a 500 g oral nickel challenge. Thus, oral nickel exposure of as little as 500 µg /day may produce adverse reactions in some nickel hypersensitive persons. US FDA (1993) suggested that a tolerable intake for nickel of 50 g/day can be derived by

applying an uncertainty factor of 10 to the lowest observed effect level for dermatitis in hypersensitive individuals, however, a daily intake of 1200 μg nickel / day was used to develop consumption levels of concern for the general population consuming shellfish.

ATSDR (1997) also discusses the same studies of contact dermatitis following oral exposure and indicates that setting of oral exposure limits for nickel is complicated by the presence of sensitized individuals in the general population.

Contact dermatitis following dermal contact with nickel was reviewed by Hostynek et al. (1993). In the context of metallic nickel in jewellery or metal utensils, where nickel can be dissolved by sweat during skin contact, reference is made to a proposed occupational limit to limit release of nickel from metal items into sweat to less than 0.5 $\mu g/cm^2$/week (or less than 0.07 $\mu g/cm^2$/day) (Hostynek et al. (1993). This nickel release to sweat exposure limit is based on work by Menne et al. (1987). The European Union has issued a directive forbidding the use of nickel in products placed in direct contact with the skin and to restrict release of nickel to less than 0.5 $\mu g/cm^2$/week during normal use for up to 2 years (ATSDR, 1997).

A2-9.2.5 Susceptible Populations

Populations which are unusually susceptible to nickel are those people already sensitive to nickel due to prolonged contact with nickel. Subsequent exposures may result in an allergic reaction. A greater number of women tend to be sensitized to nickel than men and this is believed to be related to the fact that woman tend to wear more metal jewelry than men. Further study is required to determine whether there is indeed a gender difference in nickel sensitivity. Persons with kidney dysfunction are also likely to be more susceptible to nickel as the primary route of nickel elimination is via the urine. Increased nickel serum concentrations have been observed in dialysis patients (Sudbury - Connecticut study)(ATSDR, 1997).

A2-9.3 Current Exposure Limits

It should be noted that the Health Canada (1996) exposure limits for nickel compounds cited below are based on toxicological literature reviewed up to 1993. Several major studies have been published since 1993.

A2-9.3.1 Nickel Refinery Dusts and Nickel Subsulfide

Nickel refinery dusts and nickel subsulfide are both classified by the U.S. EPA as group A: human carcinogens. Only inhalation unit risk values for these substances are available; recent noncancer values for these forms of nickel are not available. For nickel refinery dusts, the inhalation unit risk is 2.4×10^{-4} $(\mu g/m^3)^{-1}$. For nickel subsulfide, the inhalation unit risk is 4.8×10^{-4} $(\mu g/m^3)^{-1}$ (US EPA, 2001).

Health Canada (1996) reports a non-cancer tolerable inhalation concentration of 0.02 $\mu g/m^3$

for nickel subsulfide.

A2-9.3.2 Nickel Soluble Salts

The U.S. EPA (US EPA, 1998) recommended an oral RfD of 20 μg/kg-dayay for soluble salts of nickel based on decreased body and organ weight data in two year dietary study in rats (Ambrose *et al.*, 1976). This RfD may not necessarily protect the already sensitized individual.

For nickel sulphate, Health Canada (1996) derived a TDI of 50 μg/kg-dayay, based on the NOAEL from the Ambrose *et al.* (1976) two year dietary study in rats.

Toxicological Excellence for Risk Assessment (*TERA*, 1999) has conducted a review of the oral RfD for soluble nickel and has proposed a value of 7.6 μg/kg-day which does not account for nickel in the animal diet. As noted for the US EPA RfD, the *TERA* number may not necessarily protect the already sensitized individual.

For the inhalation route, Health Canada (1996) recommends a tolerable inhalation concentration (non-cancer effects) of 0.0035 $\mu g/m^3$ for nickel sulphate. The TC was based on lung and nasal lesions in rats and mice observed by Dunnick *et al.* (1989). This is based on a subchronic study, *TERA* (1999) have developed an inhalation RfC of 0.2 $\mu g/m^3$ based on a LOAEL (increased pup death) of 1.3 mg Ni / kg /day for chronic nickel chloride exposure in rats (Smith et al, 1993).

Health Canada has developed a tumorigenic dose (TD_{05}) of 0.07 mg/m^3 for soluble nickel salts.

ATSDR (1998) has developed a chronic MRL for inhalation exposure of 2×10^{-4} mg/m^3 (0.2 $\mu g/m^3$) based on a rat study of nickel sulfate hexahydrate. ATSDR did not determine oral MRLs for nickel because the protection of sensitized individuals and application of uncertainty factors to the LOAEL for contact dermatitis (0.009 mg/kg-day) would result in an MRL which would bring the dose below normal dietary intake (about 0.002 mg/kg-day in the U.S.).

A2-9.3.3 Nickel Oxide

Health Canada has not derived a chronic oral exposure limit for nickel oxide, but a tolerable inhalation concentration (non-cancer effects) of 0.02 $\mu g/m^3$ has been developed.(Health Canada, 1996).

Health Canada (1996) has classified oxidic nickel (including nickel oxide, nickel copper oxide, nickel silicate oxides and complex oxides as Group I (Carcinogenic to Humans). This classification is based on the studies of Doll et al. (1990) and the International Agency for Research in Cancer (IARC) evaluation (IARC, 1990).

It should be clarified that all toxicological information regarding the carcinogenicity of nickel

oxide, either as a component of nickel refinery dusts or as a pure compound administered to rats and mice is only by the inhalation route. There is no information regarding its carcinogenicity via the ingestion route in humans or animals. In addition, while nickel oxide has carcinogenic potential when inhaled (based on human and animal studies), there are no published inhalation unit cancer risks by which to assess its potency.

A2-9.3.4 Metallic Nickel

Health Canada (1996) reports a provisional non-cancer tolerable concentration (inhalation) of 0.018 $\mu g/m^3$.

No appropriate exposure limit (oral or dermal) for contact dermatitis was found in the literature.

For the purposes of this risk assessment, the US EPA RfD for soluble nickel was selected to assess potential noncancer effects from estimated nickel intakes from all exposure routes. Other oral exposure limits were generally below normal dietary intake estimates.

To assess the potential for cancer effects related to inhalation of nickel oxide, the annual average ambient air concentration from MOE monitoring station 27047 (at Davis and Fraser) data was compared to the US EPA inhalation unit risk of 2.4×10^{-4} $(\mu g/m^3)^{-1}$ for nickel refinery dusts. The air concentration of nickel at the 10^{-5} lifetime cancer risk (one-in-100,000) level is 0.04 $\mu g/m^3$).

Nickel refinery flue dust from INCO, Port Colborne used in animal carcinogenicity testing contained 20% nickel sulphate, 59% nickel subsuphide, and 6.3% nickel oxide (Gilman and Ruckerbauer, 1962). This flue dust has a similar composition to the nickel refinery dust mixtures that the US EPA inhalation unit risk is based on. However, INCO refinery dusts analysed for MOE and MOL in 1978 indicated that the prevalent nickel compound in INCO emissions was nickel oxide. In addition, the nickel speciation of Rodney Street soils (Results section of Part A) also indicates that nickel exposures are mainly due to nickel oxide. Consequently, since the main carcinogenic component of nickel refinery dust, namely nickel subsulphide is not present in airborne particulates inhaled by Rodney Street residents, the actual carcinogenic risk of inhaling Rodney Street air due to nickel is likely lower than inhaling real nickel refinery dusts. In this case, the inhalation risk from inhaling nickel in Rodney Street air is likely over estimated by at least ten-fold.

A2-9.3.5 Selection of Exposure Limits

Table A2-8: Selected Exposure Limits for Nickel Compounds

Route of Exposure	Exposure Limit	Toxicological Basis	Source Agency
Non-Cancer Effects			
Ingestion	20 μg/kg-day	decreased body and organ weight in rats	EPA, 1998
Inhalation			
Dermal Contact			
Cancer Effects			
Ingestion	N.A.[1]		
Inhalation	2.4×10^{-4} $(\mu g/m^3)^{-1}$	lung cancer in nickel refinery workers	EPA, 1998
Dermal Contact	N.A.		

1. Not Applicable

A2-9.4 References

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APPENDIX 3

Detailed Estimates of Daily Intakes of Metals

Detailed Estimates of Daily Intakes of Metals

The presence of elevated levels of several metals in the soil of residential properties on Rodney Street in Port Colborne has raised concerns regarding exposures experienced by residents and the potential human health effects associated with these exposures. The current assessment has been undertaken to provide interested/concerned parties with estimates of the metal exposures that could be experienced by residents of the Rodney Street community. People living in the Rodney Street community, like all residents of Ontario, are exposed to metals from a number of sources including, processed food, drinking water and air. In addition to these general exposures that are common to the population of Ontario, the residents of the Rodney Street community can be exposed to metals in the soil and in home grown produce. A detailed assessment was undertaken for people living in the Rodney Street community to develop estimates of the total daily exposure experienced by people of all ages.

A3-1 Assessing Exposures to Metals

Each of the exposure pathways identified in Section 4.1 of the main report, that can contribute to the total daily metal exposures experienced by the residents of the Rodney Street community, is discussed below. The method of calculation is presented, identifying all of the receptors and site-specific parameters that are considered for each pathway. Exposures are assessed for all of the receptors identified in Section 4.1 of the main report, and were estimated using the receptor parameters listed in Table 4-3 of the main report.

A3-1.1 Intake of Metals from Supermarket Food

Estimates of the daily dietary intakes of metals from supermarket foods are generally limited and the amount of information available varies widely between metals. The metals of concern in the Rodney Street community, addressed in this exposure assessment include, antimony, beryllium, cadmium, cobalt, copper and nickel. Information regarding daily dietary intakes of these metals has been taken from regulatory agencies in Canada and internationally. Additional information has been taken from available literature. For the purposes of assessing likely daily dietary metal intakes for the residents of the Rodney Street community, preference has been given to data generated from the Canadian population. It was felt that information from Canadian sources would provide the best reflection of likely dietary habits and metal intakes for residents of the Rodney Street community. The daily dietary intake of metals is discussed in detail in Appendix 4. A summary of the daily dietary intake of metals for all age groups is summarized in Table A3-1.

A3-1.2 Intake of Metals from Drinking Water

Daily intakes of metals from drinking water are dependent on the amount of drinking water consumed on a daily basis and the level of metals present in the drinking water. The estimated intakes of metals from drinking water for the Rodney Street community has been calculated as shown in equation A3-1. Estimates of the intake of antimony, beryllium, cadmium, cobalt, copper

and nickel from the consumption of drinking water for all age groups are shown in Table A3-2.

Table A3-1: Estimated Daily Intakes of Metals from Supermarket Food

Receptor	Daily Intakes of Metals from Supermarket Food (μg/day)					
	Antimony	Beryllium	Cadmium	Cobalt	Copper	Nickel
Infant	1.3	4.8	5.08	4.18	518	180
Toddler	2.3	8.6	10.6	7.0	822	264
Child	3.5	13.2	16.8	10.0	1230	329
Teen	4.0	15	17.3	12.0	1520	340
Adult	3.4	12.7	14.8	10.5	1430	311
Reference	FSA,1997	Vaessen & Szteke, 2000	CEPA, 1994	Dabeka & McKensie, 1995	CCME, 1997	CEPA, 1994

EQ A3-1:

$$Intake_{dw} = IR_{dw} * C_{dw}$$

Where:			
	$Intake_{dw}$	= Intake from drinking water	μg/day
	IR_{dw}	= Ingestion rate of drinking water	L/day
	C_{dw}	= Metal concentration in drinking water	μg/L

The intake estimates are based on the highest level of each metal reported by the monitoring of drinking water taken from the municipal system at Charlotte Street. Although water quality was also measured at the treatment plant, the data from within the distribution system was felt to be more representative of the water quality in the Rodney Street community. The data in Table A3-2 shows that for most metals, daily intakes from drinking water are generally less than 1 μg/day. The most notable exception to this is copper, where intakes from drinking water range between 13.2 μg/day for infants and 66 μg/day for adults. For infants and toddlers intakes of nickel from drinking water are below 1 μg/day, but intakes for children, teens and adults are greater than 1 μg/L. These values will be used in conjunction with intakes from other sources to provide estimates of total daily exposure for people in all age groups.

A3-1.3 Intake of Metals from Ambient Air

Unlike other environmental media, such as soil or water, air quality may fluctuate from day to day or hour to hour and exposure levels are also influenced by changes in meteorological conditions. To protect the general population against contaminants in outdoor air, on a continuous

basis, time periods such as 24-hours or annual are used. These prescribed time periods are referred to as "averaging times" and are an important aspect of controlling air quality. This also has significance from a toxicological perspective since the dose of a chemical, which is time dependent, is a major determinant of toxicological effects. One consideration in establishing averaging time is to limit exposure peaks for airborne chemicals, which could occur within a long averaging period, such as a year.

Table A3-2: Estimated Metal Intakes from Drinking Water

Metal	Receptor	C_{dw} (µg/L)	IR_{dw} (L/day)	$Intake_{dw}$ (µg/day)
Antimony	0- 6 months	0.97	0.3	0.29
	7 months - 4years	0.97	0.6	0.58
	5 - 11 years	0.97	0.8	0.78
	12 - 19 years	0.97	1	0.97
	20 + years	0.97	1.5	1.5
Beryllium	0- 6 months	0.20	0.3	0.06
	7 months - 4years	0.20	0.6	0.12
	5 - 11 years	0.20	0.8	0.16
	12 - 19 years	0.20	1	0.20
	20 + years	0.20	1.5	0.30
Cadmium	0- 6 months	0.083	0.3	0.025
	7 months - 4years	0.083	0.6	0.050
	5 - 11 years	0.083	0.8	0.066
	12 - 19 years	0.083	1	0.083
	20 + years	0.083	1.5	0.12
Cobalt	0- 6 months	0.040	0.3	0.012
	7 months - 4years	0.040	0.6	0.024
	5 - 11 years	0.040	0.8	0.032
	12 - 19 years	0.040	1	0.040
	20 + years	0.040	1.5	0.060
Copper	0- 6 months	44	0.3	13
	7 months - 4years	44	0.6	26
	5 - 11 years	44	0.8	35
	12 - 19 years	44	1	44
	20 + years	44	1.5	66
Nickel	0- 6 months	1.3	0.3	0.39
	7 months - 4years	1.3	0.6	0.78
	5 - 11 years	1.3	0.8	1.0
	12 - 19 years	1.3	1	1.3
	20 + years	1.3	1.5	2.0

Averaging time can be used to ensure protection against the different effects of airborne chemicals by ensuring that exposure limits for specific effects, acute or chronic, are not exceeded. Short term acute effects are normally based on a 1-hour (or less) exposure period while longer term chronic effects are based on a 24-hour or annual averaging time. Averaging times also provide useful benchmarks to monitor ambient air quality

The time taken for chemical exposure to cause adverse health effects varies among chemicals and even a single chemical can cause different effects at different doses. Chemicals such as sulphur dioxide, may trigger an effect within 15 minutes, or less, of exposure. Others, such as the carcinogenic chemicals, may have a longer-term cumulative effect, which may not clinically manifest for several years. The times over which concentrations should be averaged to reflect the timeframe during which their effects become apparent varies, and averaging times are often set to reflect this.

Air monitoring data is usually collected on air samplers over relatively short time periods, e.g., one to two days, and the results integrate the chemical concentration over the volume of air filtered and the time period the sampler was running. A single air sample would result in the air concentration over a daily time period. In the course of a year, if sufficient "daily" samples are taken, an annual average air concentration can be calculated. This way a picture of the peak levels and the overall average concentration in the air over the year can be constructed.

In the case of the risk assessment for the Rodney Street community, air monitoring data comes from several sources and locations. Local air sampling for nickel, lead, copper and total suspended particulates was obtained from the Ministry's sampling station at Davis St & Fraser St which operated from 1992 to 1996, and air sampling done during the summer of 2000 near schoolyards in Port Colborne by Jacques Whitford Environmental Limited (JWEL, 2000). The Ministry's sampling station is about 600 m north of Rodney Street. Prevailing winds in the general Port Colborne area are from the west and southwest. Those sectors account for about 45-50% of winds. The other sectors occur less and fairly evenly, about 5-15% each (Frank Dobroff, MOE, personal communication). While the Davis & Fraser location may be deemed slightly upwind of the Rodney Street community, inspection of the nickel concentration in soil maps in the Ministry's Phytotoxicology Soil Investigation reports (MOE, 1999; MOE, 2000) indicate that it is located in an area where nickel levels in surface soils range up to 1000 µg/g, and depending on wind direction would sample air particulates representative of the area just north of Rodney Street. The air monitoring performed at Port Colborne schools in the summer of 2000(JWEL 2000) was only collected for the portion of the year that dust levels would normally be higher and may not be representative of long term average levels in the community. In all cases where air monitoring data exists for arsenic, cobalt, copper, nickel, and TSP, the maximum and average air concentrations for each metal from the JWEL (2000) air monitoring are less than or comparable with either the MOE or Environment Canada information.

Air concentrations of other metals not sampled extensively in Port Colborne (antimony, arsenic, , cadmium, cobalt, lead) were taken from Environment Canada's National Air Pollution Surveillance (NAPS) air monitoring program for Ontario for 1995-1999 (Tom Dann, Environment Canada, personal communication). Environment Canada air monitoring data comes from nine sites spread across Ontario, six of which are in Hamilton, Toronto and Windsor. In general, the Environment Canada air monitoring data for the same chemicals sampled by MOE at Davis and Fraser (the maximum and annual average air concentrations) was lower. In the absence of more suitable air quality data for chemicals not sampled extensively in Port Colborne, Environment Canada air monitoring data was used.

Air monitoring data for beryllium is not available either from Environment Canada or MOE air monitoring programs. In order to estimate potential health effects from inhaling airborne beryllium in the Rodney Street community, it was assumed that the total suspended particulates

(TSP) data from MOE monitoring at Davis & Fraser for 1992-1996 would have the same beryllium concentration as soil in the Rodney Street community.

As a check on the possible relationship between soil metal concentrations and metal levels in resuspended dust, the same calculation using the highest average TSP concentration from MOE monitoring at Davis & Fraser for 1992-1996 and the highest surface soil metal concentration in soil in the Rodney Street community is shown in Table A3-3. In general, these artificial resuspended soil as TSP calculations fall into a range overlapping the other air monitoring data since the artificial numbers range from near the highest annual average (antimony, cadmium, copper) to near the maximum air concentrations (arsenic, cobalt, lead and nickel) found in the MOE or Environment Canada air monitoring data. A summary of the metal levels in air, used in the current assessment is provided in Table A3-3

Table A3-3: Levels of Metals in Ambient Air in Port Colborne

	Metal Concentration in Air in Port Colborne ($\mu g/m^3$)					
	Antimony	Beryllium	Cadmium	Cobalt	Copper	Nickel
Short term maximum	0.0115	n/a	0.0067	0.017	0.56	0.69
Annual average (highest)	0.0011	0.00012	0.0007	0.002	0.11	0.033
Resuspended soil calculation	0.0012	0.00012	0.00026	0.012	0.057	0.55

To assess the potential health risks related to inhalation, the highest annual average air concentration from the MOE or Environment Canada air monitoring data was used. This is more appropriate to estimate long term inhalation exposure, and, inhalation R*f*C and unit risks are developed for lifetime exposure not short term maximum air concentrations. Characterization of potential health risks from inhalation is discussed in Section 5.0 of the Human Health Risk Assessment main report (Part B)(Risk Characterization).

In the Rodney Street community, inhaled metals will be associated with particulate matter and will not be present as free metal. Therefore, there is a potential for the inhaled particulate matter to be cleared from the lungs, through mucocilliary transport, and swallowed. Material cleared from the lungs in this fashion will add to the total daily ingestion of metal. The amount of particulate delivered to the stomach by this process is difficult to predict with any accuracy. Therefore, to provide conservative estimates of the amount of metal ingested as a result of the clearance of inhaled particles, it has been assumed that all inhaled metal is cleared from the lung and passed to the stomach. This approach will over estimate the contribution that inhalation exposures make to the total daily intakes of metals. The estimated inhalation intake of each metal for each receptor based on the highest annual average level (Table A3-3) is shown in Table A3-4. These values are calculated as shown in equation A3-2.

Eq A3-2:

$$Intake_{air} = IR_{air} * C_{air}$$

Where:			
	$Intake_{air}$	= Intake from air	µg/day
	IR_{air}	= Inhalation rate	m^3/day
	C_{air}	= Metal concentration air	µg/m^3

Table A3-4: Estimated Metal Intakes from Air

Metal	Receptor	C_{air} (µg/m^3)	IR_{air} (m^3/day)	$Intake_{air}$ (µg/day)
Antimony	0- 6 months	0.0011	3.2	0.0035
	7 months - 4years	0.0011	14.6	0.016
	5 - 11 years	0.0011	20.3	0.022
	12 - 19 years	0.0011	23.1	0.025
	20 + years	0.0011	22.9	0.025
Beryllium	0- 6 months	0.00012	3.2	0.00038
	7 months - 4years	0.00012	14.6	0.0018
	5 - 11 years	0.00012	20.3	0.0024
	12 - 19 years	0.00012	23.1	0.0028
	20 + years	0.00012	22.9	0.0027
Cadmium	0- 6 months	0.0007	3.2	0.0022
	7 months - 4years	0.0007	14.6	0.010
	5 - 11 years	0.0007	20.3	0.014
	12 - 19 years	0.0007	23.1	0.016
	20 + years	0.0007	22.9	0.016
Cobalt	0- 6 months	0.002	3.2	0.0064
	7 months - 4years	0.002	14.6	0.029
	5 - 11 years	0.002	20.3	0.041
	12 - 19 years	0.002	23.1	0.046
	20 + years	0.002	22.9	0.046
Copper	0- 6 months	0.112	3.2	0.36
	7 months - 4years	0.112	14.6	1.6
	5 - 11 years	0.112	20.3	2.3
	12 - 19 years	0.112	23.1	2.6
	20 + years	0.112	22.9	2.6
Nickel	0- 6 months	0.033	3.2	0.11
	7 months - 4years	0.033	14.6	0.48
	5 - 11 years	0.033	20.3	0.67
	12 - 19 years	0.033	23.1	0.76
	20 + years	0.033	22.9	0.76

A3-1.4 Intake of Metals from Backyard Garden Produce

Eating vegetables grown in backyards where metal levels are above typical levels, represents

a potential exposure pathway if the metals present in the soil are taken up into the vegetables. The exposures received by people eating such produce depends upon the concentration of the metals in the vegetables and the amount of vegetables consumed from backyard gardens. The current assessment has assumed that backyard garden produce is consumed on a daily basis throughout the year. The amount of backyard garden vegetables consumed on a annually averaged daily basis is discussed in detail in Appendix 6.

As part of the on-going work in Port Colborne, samples of backyard produce have been collected by the MOE and JWEL from Rodney and Mitchell Streets. The levels of individual metals in the various types of produce tested are provided in Appendix 1 of this report. For the purposes of this assessment, backyard garden produce has been divided into two general categories;

root vegetables includes; beet root and radish samples from Rodney and Mitchell Street gardens and the Wainfleet bog

other vegetables. includes; beet tops, celery, lettuce, peppers and tomatoes from Rodney and Mitchell Street gardens and the Wainfleet bog

A review of the vegetable data in Appendix 1 clearly shows that the concentrations of metals in vegetables is not strongly affected by the levels of metals present in the soil (see Table A3-5). The data in Table A3-5 provides a comparison of metal levels in soil and vegetables between various locations in the Port Colborne vicinity. For comparisons to be possible, metal levels must have been reported in the same crop from differing locations and metal levels in soil must also have been available. With the available data it was possible to develop comparisons for four of the six metals of concern including cadmium, cobalt, copper and nickel. Similar comparisons were not possible for antimony or beryllium.

Table A3-5: Comparison of Metal Levels in Soil and Vegetables

Vegetable	Location	Metal Levels in Soil and Vegetables (µg/g)							
		Cadmium		Cobalt		Copper		Nickel	
		Soil	Veg	Soil	Veg	Soil	Veg	Soil	Veg
Beet Root	Rodney Loc #3	<0.5	0.049	20.1	0.048	134	1.92	764	1.82
	Rodney Loc #25	1.1	0.031	28.6	0.014	194	1.26	1570	1.37
	Wainfleet Bog	15.6	0.04	4.5	0.014	14.9 -22.2	1.03	15.6	0.027
Tomato	Rodney Loc 3	<0.5	0.015	20.1	0.0059	134	0.66	764	0.21
	MOE Sample # 1	0.8	0.013	44.5	0.0065	220	0.32	2750	0.35
	MOE Sample # 2	0.1	0.013	58	0.0065	325	0.3	4400	0.31
Pepper	Rodney Loc #25	1.1	0.0099	28.6	0.0033	194	0.67	1570	0.52
	MOE Sample # 1	0.8	0.0033	44.5	0.0066	220	0.39	2750	0.92
	MOE Sample # 2	0.1	0.013	58	0.0066	325	0.62	4400	1.58
	Wainfleet Bog	15.6	0.059	4.5	0.037	14.9 -22.2	0.98	15.6	0.039

1: metal levels in vegetables are reported on a fresh weight basis

In soil in the Rodney Street community where cadmium levels were less than 0.5 µg/g, cadmium levels in beets was 0.049 µg/g on a fresh weight basis. These levels are marginally higher than the level of 0.040 µg/g reported in beets from the Wainfleet Bog where cadmium levels ranged

between 15.4 and 15.8 µg/g (average 15.6 µg/g). Similar trends can bee seen for all the metals listed in Table A3-5 and for all of the vegetables examined. This lack of a relationship between metal concentrations in soil and vegetables is most likely due to the relative insolubility of the metals of concern. The metals present in the soil will be bound to, or associated with, soil particles and will not be easily solubilized: As a result, they are not readily available for uptake into plants. Because there does not appear to be a relationship between metal levels in the soil and the levels in vegetable grown in the soil, metal levels in vegetables cannot be predicted on the basis of metal concentrations in soil. Therefore the highest levels reported in root and other vegetables from gardens in the Rodney Street community, the MOE samples and those taken from Wainfleet bog were used to assess potential intakes of metals from backyard produce in Port Colborne. To ensure that the data from the Rodney Street community would match the same categories used by Health Canada, the vegetables analyzed from the Rodney Street community were placed into two groups; *Root vegetables* and *Other Vegetables.* The metal levels used in this assessment are summarized in Table A3-6.

Table A3-6: Metal Levels in Backyard Produce in Port Colborne

Vegetable	Metal Concentrations in Vegetables (µg/g) (Fresh Weight)							
	Antimony	Arsenic	Beryllium	Cadmium	Cobalt	Copper	Lead	Nickel
Root Vegetables	0.008	0.011	-	0.049	0.048	1.92	1.05	1.82
Other Vegetables	0.021	0.007	0.007	0.063	0.083	1.06	0.25	1.58

The highest level of each metal reported in both of these categories were used to estimate daily intakes of metals from backyard garden produce. Daily intakes of metal from backyard produce are calculated as shown in equation A3-3. Estimates of daily metals intakes from backyard garden vegetables for all age groups are shown in Table A3-7

A3-1.5 Intake of Metals from Soil

The metals of concern in the Rodney Street community area of Port Colborne are generally tightly bound to soil particles and are present in forms that either have limited solubility in water or are largely insoluble. However, the solubility of these metals increases under acidic conditions. When ingested, metals that are insoluble in water at neutral pH (6.0 - 8.0) can be solubilized and removed from soil particles in the acidic environment of the stomach. The metals released from the soil in the stomach become accessible for uptake by the gut. Ingested metals that remain bound to soil particles in the gut are not available for absorption and are excreted in the feces. The daily intake of metal from ingested soil is a function of the amount of soil ingested, the level of metal contained in the soil and the amount of metal released from the soil particles under the acidic conditions of the stomach. The estimated daily intake of metal from the ingestion of soil is calculated as shown in equation A3-4.

EQ A3-3:

$$Intake_{veg} = \left(IR_{root} * C_{root}\right) + \left(IR_{other} * C_{other}\right)$$

Where:			
	$Intake_{vegl}$	= Intake from backyard garden produce	µg/day
	IR_x	= Yearly averaged daily intake of backyard root or other vegetables (see Appendix 6)	g/day
	C_x	= Metal concentration in root/other vegetables	µg/g

Table A3-7: Estimated Metal Intakes from Backyard Vegetables

Metal	Receptor	Root Vegetables			Other Vegetables			Total
		Cx (µg/g)	IR_x (g/day)	$Intake_{air}$ (µg/day)	Cx (µg/g)	IR_x (g/day)	$Intake_{air}$ (µg/day)	(µg/day)
Antimony	0- 6 months	0.008	8.18	0.065	0.021	7.09	0.15	0.21
	7 months -	0.008	10.3	0.082	0.021	6.60	0.14	0.22
	5 - 11 years	0.008	15.9	0.13	0.021	9.65	0.20	0.33
	12 - 19 years	0.008	22.4	0.18	0.021	11.8	0.25	0.43
	20 + years	0.008	19.3	0.15	0.021	14.1	0.30	0.45
Beryllium	0- 6 months	0	8.18	0.00	0.0066	7.09	0.047	0.05
	7 months -	0	10.3	0.00	0.0066	6.60	0.044	0.04
	5 - 11 years	0	15.9	0.00	0.0066	9.65	0.064	0.06
	12 - 19 years	0	22.4	0.00	0.0066	11.8	0.078	0.08
	20 + years	0	19.3	0.00	0.0066	14.1	0.093	0.09
Cadmium	0- 6 months	0.049	8.18	0.40	0.063	7.09	0.45	0.85
	7 months -	0.049	10.3	0.50	0.063	6.60	0.42	0.92
	5 - 11 years	0.049	15.9	0.78	0.063	9.65	0.61	1.4
	12 - 19 years	0.049	22.4	1.1	0.063	11.8	0.74	1.8
	20 + years	0.049	19.3	0.95	0.063	14.1	0.89	1.8
Cobalt	0- 6 months	0.048	8.18	0.39	0.083	7.09	0.59	0.98
	7 months -	0.048	10.3	0.49	0.083	6.60	0.55	1.0
	5 - 11 years	0.048	15.9	0.76	0.083	9.65	0.80	1.6
	12 - 19 years	0.048	22.4	1.1	0.083	11.8	0.98	2.1
	20 + years	0.048	19.3	0.93	0.083	14.1	1.2	2.1
Copper	0- 6 months	1.92	8.18	16	1.06	7.09	7.5	23
	7 months -	1.92	10.3	20	1.06	6.60	7.0	27
	5 - 11 years	1.92	15.9	31	1.06	9.65	10	41
	12 - 19 years	1.92	22.4	43	1.06	11.8	13	56
	20 + years	1.92	19.3	37	1.06	14.1	15	52
Nickel	0- 6 months	1.82	8.18	15	1.58	7.09	11	26
	7 months -	1.82	10.3	19	1.58	6.60	10	29
	5 - 11 years	1.82	15.9	29	1.58	9.65	15	44
	12 - 19 years	1.82	22.4	41	1.58	11.8	19	59
	20 + years	1.82	19.3	35	1.58	14.1	22	57

Eq A3-4:

$$Intake_{soil} = IR_{soil} * C_{soil} * Bio_{soil}$$

Where:			
	$Intake_{soil}$	= Intake from soil	µg/day
	IR_{soil}	= Soil ingestion rate	g/day
	C_{soil}	= Metal concentration in soil	µg/g
	Bio_{soil}	= % of metal release from soil in stomach	unitless

The soil ingestion rates for each of the receptor age groups are listed in Table 4-3 of the main report. The highest reported level of each metal in the soil from the Rodney Street community was used to estimate the daily ingestion of metal from soil. The $\boldsymbol{Bio_{soil}}$ parameter is a measure of the amount of metal that is released from the soil under the acidic conditions of the stomach. This represents the amount of metal the is considered to be bio-accessible, or available to the gut for uptake, from the soil. The amount of each metal released from the soil in the stomach has been estimated using a simulated stomach acid leach test. The test methodology is discussed in detail in Appendix 5. The results of the stomach acid leach test for each metal are also provided in Appendix 5. For each metal, the maximum reported result was used to estimate the amount of metal that would be bio-accessible. This was used to estimate the effective daily intake for each metal from soil. The estimated daily intake of each metal from the soil is shown in Table A3-8.

A3-1.6 Intake of Metals Through Dermal Contact with Soil

Daily contact with metals through soil present on the skin represents a potential route of exposure. However, the insoluble nature of most metals in soil limits their bio-accessability for uptake into and through the skin. Where data is available, it shows that dermal uptake of metals is low (Paustenbach, 2000). The rate at which a metal is taken up into the outer layers of the skin is referred to as the *dermal uptake coefficient* (DUC). For the purposes of the current exposure assessment, the dermal uptake coefficients have been used to represent the amount of metal delivered to the skin surface from the soil that would be accessible for uptake. This is considered to be the *delivered dose* and is has been considered to be equivalent to the dermal intake. A detailed discussion of the derivation of the DUC values for each of the metals in provided in Appendix 7. The delivered dose, is calculated as shown in equation A3-6. These values have been used in conjunction with the estimates of intake from other sources to provide an estimate of the total daily dose for each age group for each metal (Table A3-9).

Eq A3-6:

$$Intake_{derm} = A_{soil} * C_{soil} * DUC_{soil}$$

Where:	$Intake_{derm}$	= Dermal Intake from soil	µg/day
	A_{soil}	= Soil adhesion to skin	g/day
	C_{soil}	= Metal concentration soil	µg/g
	DUC_{soil}	= Dermal uptake coefficient	unitless

Table A3-8: Estimated Metal Intakes from Soil

Metal	Receptor	C_{soil} (µg/g)	IR_{soil} (g/day)	Bio_{soil}	Total (µg/day)
Antimony	0- 6 months	91.1	0.035	0.0019	0.0062
	7 months - 4years	91.1	0.080	0.0019	0.014
	5 - 11 years	91.1	0.080	0.0019	0.014
	12 - 19 years	91.1	0.020	0.0019	0.0035
	20 + years	91.1	0.020	0.0019	0.0035
Beryllium	0- 6 months	4.56	0.035	0.0019	0.00030
	7 months - 4years	4.56	0.080	0.0019	0.00069
	5 - 11 years	4.56	0.080	0.0019	0.00069
	12 - 19 years	4.56	0.020	0.0019	0.00017
	20 + years	4.56	0.020	0.0019	0.00017
Cadmium	0- 6 months	35.3	0.035	0.0019	0.0023
	7 months - 4years	35.3	0.080	0.0019	0.0054
	5 - 11 years	35.3	0.080	0.0019	0.0054
	12 - 19 years	35.3	0.020	0.0019	0.0013
	20 + years	35.3	0.020	0.0019	0.0013
Cobalt	0- 6 months	262	0.035	0.0123	0.11
	7 months - 4years	262	0.080	0.0123	0.26
	5 - 11 years	262	0.080	0.0123	0.26
	12 - 19 years	262	0.020	0.0123	0.064
	20 + years	262	0.020	0.0123	0.064
Copper	0- 6 months	2720	0.035	0.0222	2.1
	7 months - 4years	2720	0.080	0.0222	4.8
	5 - 11 years	2720	0.080	0.0222	4.8
	12 - 19 years	2720	0.020	0.0222	1.2
	20 + years	2720	0.020	0.0222	1.2
Nickel	0- 6 months	17000	0.035	0.0116	6.9
	7 months - 4years	17000	0.080	0.0116	16
	5 - 11 years	17000	0.080	0.0116	16
	12 - 19 years	17000	0.020	0.0116	3.9
	20 + years	17000	0.020	0.0116	3.9

Table A3-9: Estimated Metal Intakes from Dermal Contact with Soil

Metal	Receptor	C_{soil} (µg/g)	A_{soil} (g/day)	DUC_{soil}	$Intake_{derm}$ (µg/day)
Antimony	0- 6 months	91.1	2.2	0.00190	0.38
	7 months - 4years	91.1	3.5	0.00190	0.61
	5 - 11 years	91.1	5.8	0.00190	1.0
	12 - 19 years	91.1	9.1	0.00190	1.6
	20 + years	91.1	8.7	0.00190	1.5
Beryllium	0- 6 months	4.56	2.2	0.00190	0.019
	7 months - 4years	4.56	3.5	0.00190	0.030
	5 - 11 years	4.56	5.8	0.00190	0.050
	12 - 19 years	4.56	9.1	0.00190	0.079
	20 + years	4.56	8.7	0.00190	0.075
Cadmium	0- 6 months	35.3	2.2	0.00190	0.15
	7 months - 4years	35.3	3.5	0.00190	0.23
	5 - 11 years	35.3	5.8	0.00190	0.39
	12 - 19 years	35.3	9.1	0.00190	0.61
	20 + years	35.3	8.7	0.00190	0.58
Cobalt	0- 6 months	262	2.2	0.0004	0.23
	7 months - 4years	262	3.5	0.0004	0.37
	5 - 11 years	262	5.8	0.0004	0.61
	12 - 19 years	262	9.1	0.0004	0.95
	20 + years	262	8.7	0.0004	0.91
Copper	0- 6 months	2720	2.2	0.02200	132
	7 months - 4years	2720	3.5	0.02200	209
	5 - 11 years	2720	5.8	0.02200	347
	12 - 19 years	2720	9.1	0.02200	545
	20 + years	2720	8.7	0.02200	521
Nickel	0- 6 months	17000	2.2	0.000380	14
	7 months - 4years	17000	3.5	0.000380	23
	5 - 11 years	17000	5.8	0.000380	37
	12 - 19 years	17000	9.1	0.000380	59
	20 + years	17000	8.7	0.000380	56

A3-2 Summary

For each receptor age group daily metal intakes have been estimated for each of the pathways of concern. For each metal, intakes from all exposure pathways must be combined for each receptor in order to estimate the total daily dose received by each receptor age group. This summation of exposures is presented in Section 4.4 of the Human Health Risk Assessment main report (Part B).

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APPENDIX 4

Estimating Daily Intakes of Metals from Supermarket Food

Estimating Metal Intakes from Supermarket Food

Estimates of the dietary intakes of metals from supermarket food by the general Canadian population are limited. Daily dietary intake estimates for arsenic, cadmium, copper and nickel have been published by CEPA (Health Canada and Environment Canada) and CCME (see Table A4-1). Sources of similar estimates for cobalt and lead are listed in Table A4-1. Information on dietary intakes for all age groups is not available for all metals. For example, information on dietary intakes of antimony and beryllium are limited to single estimates of daily intake by the general population (FSA, 1997, Vaessen and Szteke, 2000).

A4-1 Estimating Dietary Intakes of Metals for All Age Groups

The lack of dietary intakes for all age groups used in this assessment required that intake estimates be derived from available information. The shaded areas in Table A4-1 indicate where such derivations have been necessary.

Table A4-1: Estimated Daily Intakes of Metals from Supermarket Food

Receptor	Daily Intakes of Metals from Supermarket Food (µg/day)					
	Antimony	Beryllium	Cadmium	Cobalt	Copper	Nickel
Infant	1.3	4.8	5.08	4.18	518	180
Toddler	2.3	8.6	10.6	7.0	822	264
Child	3.5	13.2	16.8	10.0	1230	329
Teen	4.0	15	17.3	12.0	1520	340
Adult	3.4	12.7	14.8	10.5	1430	311
Reference	FSA, 1997	Vaessen & Szteke, 2000	CEPA, 1994a	Dabeka & McKensie, 1995	CCME, 1997	CEPA, 1994b

Shaded cells represent calculated values (see text for explanations)

CEPA and CCME provide daily dietary intake estimates for arsenic, cadmium, copper and nickel for all age groups. The age groups examined by Dabeka and McKensie (1995) differ slightly from those used by CEPA and CCME. Dabeka and McKensie (1995) do not report intakes for children age 0 - 1 year, and their toddler age group includes children aged 1 - 4 years rather than the 7 months to 4 years used by Health Canada and CCME. Dabeka and McKensie (1995), Health Canada and CCME use the same age groupings for children (5 - 11 years), teens (12 - 19 years) and adults (20+ years). For the purposes of this assessment the intake estimates provided by Dabeka and McKensie (1995) for cobalt for toddlers, have been applied to the toddler (7 months - 4 years) used in this assessment. The cobalt intakes for infants, shown in Table A4-1 have been estimated based on the intakes reported for toddlers. The ratios were determined by averaging the ratios of infant and toddler intakes for arsenic, cadmium, copper and nickel as shown in equation A4-1. The estimated intakes for cobalt were derived by correcting the toddler intakes for cobalt (Table A4-1).

Eq A4-1:

$$C_I = \left[\frac{\left(\frac{I_{As}}{T_{As}}\right) + \left(\frac{I_{Cd}}{T_{Cd}}\right) + \left(\frac{I_{Cu}}{T_{Cu}}\right) + \left(\frac{I_{Ni}}{T_{Ni}}\right)}{4} \right] = 0.598$$

Where: C_I = Correction factor for infant intake
I_x = Infant intake for arsenic, cadmium, copper, and nickel
T_x = Toddler intake for arsenic, cadmium, copper, and nickel

A4-2 Additional Information on Dietary Intakes for Antimony, Beryllium and Nickel

Dietary intake information for antimony and beryllium is limited to a single, general population estimate for each (FSA, 1997; Vaessen and Szteke, 2000). In order to develop likely total daily intakes from supermarket foods for all age groups of concern in this assessment, the single values have been used as a basis for estimating intakes in all age groups. A ratio process similar to the one outlined in Equation A4-1 was used. The estimated daily intakes of antimony and beryllium are 4 µg/day (FSA, 1997) and 15 µg/day (Vaessen and Szteke, 2000), respectively. A review of intake data for the other metals shows that the highest daily intakes of metals occurs in the "teen" age group for all metals considered (See Table A4-1). Therefore, the values reported for antimony and beryllium were assigned to this age group. Ratios for metal intakes between the teen age group and the other age groups were developed for arsenic, cadmium, cobalt and lead. The average of these values for each of the age groups was used to generate the intake estimates for antimony and beryllium for each of the age groups. The derivation of the ratios is shown in Table A4-2.

Table A4-2: Dietary Intake Ratios for different Age groups for Arsenic, Cadmium, Cobalt and Lead.

Receptor	Daily Intakes of Metals from Supermarket Food (µg/day)								Averaging Ratio
	Arsenic		Cadmium		Cobalt		Lead		
	Intake	Ratio	Intake	Ratio	Intake	Ratio	Intake	Ratio	
Infant	19.70	0.28	5.08	0.29	4.18	0.35	8.97	0.37	0.32
Toddler	33.00	0.46	10.60	0.61	7.00	0.58	15.00	0.63	0.57
Child	62.50	0.87	16.80	0.97	10.00	0.83	20.00	0.83	0.88
Teen	71.60	1.00	17.30	1.00	12.00	1.00	24.00	1.00	1.00
Adult	42.40	0.59	14.80	0.86	10.50	0.88	25.70	1.07	0.85

Because nickel and copper can be added during food processing operations, it was felt that the levels of these metals would not provide a true reflection of trace metal levels in foods. Therefore nickel and copper were not considered in the development of the ratios used to estimate the daily intakes of the trace metals antimony and beryllium.

A4-2.1 Antimony

There is very limited data on dietary intakes of antimony in general/supermarket food. ATSDR (1990) estimated that the antimony concentration in the diet of a typical adult male was 9.3 μg/kg dry weight. The WHO used the information cited by the ATSDR to develop an estimate of the daily intake of antimony from food of 18 μg/day (WHO, 1996). Two studies that post-date the work cited by ATSDR and the WHO have also examined dietary intakes of antimony (FSA, 1997 and Miahara *et al.*, 1998). Miahara *et al.* examined antimony intakes in preschool children and the elderly in Brazil. Estimates of dietary intake ranged between 1.1 μg/day and 2.3 μg/day. The Food Standards Agency in Great Britain estimated dietary intakes of antimony in the British population. The study found a mean daily intake of 3 μg/day with a 97.5 percentile estimate of 4 μg/day. The study further noted that these values are approximately 10-fold lower than the previous estimate of 29 μg/day that was based on a 1976 survey. The difference was attributed to a significant lowering of analytical detection limits between the time of the two studies (FSA, 1997). Although the WHO suggested a daily intake of 18 μg/day in 1996, this value was based on estimates developed before changes in analytical techniques allowed for better estimates of antimony levels in foods. As a result, the WHO value is likely to over estimate daily dietary intakes of antimony. For the purposes of this assessment, the upper estimate of 4 μg/day suggested by the FSA has been used to estimate dietary intakes of antimony for the residents of Rodney Street in Port Colborne. The upper FSA estimate (4 μg/day) was assumed to be a lifetime daily intake for a typical Rodney Street teen and was prorated to average estimates of supermarket food intake for other age classes as shown in Table A4-3.

A4-2.2 Beryllium

Information on the dietary exposure to beryllium is limited. Recently, a review of the worldwide literature on the occurrence of beryllium in food and drinking water and estimates of daily dietary exposure was sponsored by the Food Chemistry Commission of the International Union for Pure and Applied Chemistry (IUPAC)(Vaessen and Szteke, 2000). Beryllium levels in food were found to range from <1 to approximately 20 μg/kg fresh weight. In the US, the average beryllium concentration in drinking water is 0.2 μg/L. Estimates of beryllium intake from food consumption for the UK and the US ranged from 12 to 15 μg/day, however, these food intakes were considered to be rough estimates. The 15 μg/day estimate was assumed to be a lifetime daily intake for a typical Rodney Street teen and was prorated to average estimates of supermarket food intake for other age classes as shown in Table A4-3.

Table A4-3: Sample Calculation of Estimated Dietary Intakes for Each Age Class using Averaging Ratios.

Receptor	Averaging Ratio	Daily Intakes of Metals from Supermarket Food (µg/day)			
		Antimony		Beryllium	
		Reported	Calculated	Reported	Calculated
Infant	0.3227		1.3		4.8
Toddler	0.5705		2.3		8.6
Child	0.8777		3.5		13.2
Teen	1.0000	4.0	4.0	15.0	15.0
Adult	0.8484		3.4		12.7

A4-2.3 Nickel

Interpreting information from dietary intake studies requires assessing a whole range of information from levels of nickel in specific food items to how this information is integrated into overall population intakes by age class and averages and percentiles for each age class. Some agencies report just average intakes for the adult population, others indicate upper ranges of intake, as well, and sometimes just a range of intakes is reported. Consequently, the full range of intakes reported by various agencies is tabulated in Table A4-4.

Several studies have attempted to estimate the daily intake of nickel from supermarket or processed food in the Canadian and North American populations. Based on the US Food and Drug Administration's Total Diet Study of 1984, the mean nickel consumption of infants and young children was 69 to 90 µg/day (Pennington and Jones, 1987). Average daily dietary intake of nickel in the US has been reported as 168 µg/day (Myron et al., 1978; cited in ATSDR, 1997). A more recent review of dietary intake has included nickel intakes from dietary supplements and estimates that adults consume 76 to 105 µg/day of nickel from diet and supplements (IOM, 2001). The US dietary intake data formatted to match the Canadian age class groups is shown in Table A4-4.

A 1984 market basket survey of dietary nickel intake in England determined an intake of 154-166 µg/day (Smart and Sherlock, 1987). More recently, the results of the 1997 UK Total Diet Study were published (Ysart et al., 2000). The average dietary exposure for UK adults was 120 µg/day and the 97.5th percentile was 210 µg/day, similar to their 1994 survey. This information was prorated to Canadian age class intervals using the averaging ratios in Table A4-3 is shown in Table A4-4.

CEPA, provides estimates of daily nickel intakes from food for the general Canadian population (CEPA, 1994b). These estimates are based on a survey of nickel concentrations in various foods conducted by National Health and Welfare, 1992 and estimates of age-specific food intakes derived from a Nutrition Canada, Environmental Health Directorate survey (CEPA, 1994c). More detailed information on dietary intakes of nickel by Canadians was reported in Dabeka and McKensie (1995). The Canadian dietary intake of nickel for all ages, male and female, is 286 µg/day

(Dabeka and McKensie (1995). It is not indicated whether the Canadian dietary intakes are averages or some upper range, however, inspection of the tables of nickel levels in various food categories indicates that the reported Canadian dietary intakes are average values.

Inspection of Table A4-4 shows that Canadian dietary nickel intakes are higher than US and UK estimates. Dabeka and McKensie (1995) comment on this situation and indicate that the highest nickel intakes were for meat and poultry (about 40%), bakery goods and cereals (about 19%), soups (about 15%) and vegetables (about 11%). These data are felt to provide the best representation of likely nickel intakes from food for the Canadian population as a whole. Therefore these values have been used to represent the intake of nickel from non-home grown food sources for the residents of Rodney Street (Table A4-1).

Table A4-4: Estimated Daily Dietary Intake of Nickel for Various Countries

Medium	Daily Intake 0 - 6 mon (µg/day)	Daily Intake 1 - 4 yr (µg/day)	Daily Intake 5-11yr (µg/day)	Daily Intake 12-19 yr (µg/day)	Daily Intake Adult (µg/day)
CEPA, 1994b	154	208	270	325	308
Dabeka and McKensie, 1995	(80)	190	251	313	304
US FDA Total Dietary Study (95th %ile) (IOM, 2001)	9(37)	81(153)	107(199)	125(250)	119(233)
UK Total Dietary Study 1997 (97.5th %ile) (Ysart et al, 2000)	39(68)	68(120)	105(184)	120(210)	102(178)

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APPENDIX 5

Simulated Stomach Acid Leach Tests

Simulated Stomach Acid Leach Tests

The metals of concern in the Rodney Street area of Port Colborne are generally tightly bound to soil particles and are present in forms that either have limited solubility in water or are largely insoluble. However, the solubility of these metals increases under acidic conditions. When ingested, metals that are insoluble in water at neutral pH (6.0 - 8.0) can be solubilized and removed from soil particles in the acidic environment of the stomach. The metals released from the soil in the stomach become available for uptake by the gut. Ingested metals that remain bound to soil particles in the gut are not available for absorption and are excreted in the feces. Elimination in the feces is the primary route of excretion following ingestion for each of the metals of concern. The elimination of ingested metals is discussed in the toxicological profile for each metal (Appendix 2).

The oral exposure limits identified for all of the metals of concern, except lead, are based on experimental animal data where metals were administered in soluble forms. Thus, the reported doses are based on free or soluble metal levels administered. Under the conditions that exist in the Rodney Street area of Port Colborne, metals ingested with soil will largely be present as insoluble forms, are not available in the gut, and do not form a component of the administered dose that is available for uptake. Thus, this component of the dose should not be considered in the estimation of exposure. The metals that are released from the soil particles during acid digestion in the stomach can be considered to be equivalent to the soluble forms of metals administered during toxicological testing. The inclusion of all ingested metal in the assessment of exposure will over represent the amount of metal actually available in the gut. The current assessment has attempted to account for this discrepancy by determining the amount of metal that could be released from soil particles in the acidic environment of the stomach, by subjecting the soil to a simulated stomach acid digest. The amount of each metal released from the soil particles (leached) was used to represent the amount of metal that was bio-accessible (the effective amount of metal ingested). These values were used to determine metal ingestion levels from soil as part of the exposure assessment.

Ten soil samples from the Rodney Street area, containing very high levels of nickel were selected for simulated stomach acid leach testing. For each soil sample, 20 g of dried, sieved material was added to 400 ml of 0.17 N HCl (pH 1.0). The samples were agitated for 24 hours on a rotary extractor. The mixture was then filtered through a 4.5 micron filter and the filtrate was analyzed for metals and hydrides. For each sample, the percentage leached was calculated by dividing the concentration of the metal in the leachate by the concentration in the original soil sample and the multiplying the ration by 100. The results of the analyses are shown in Tables A5-1 through A5-8. The maximum reported leached value was used to represent the amount of each metal that would be released from the soil in the stomach and would be available to contribute to actual exposures.

It is recognized that the use of a 24 hour digestion period, which is longer than the typical residency times for food in the stomach, will overestimate the amount of metal that will be released and available. However, it was believed that as a precautionary measure, the potential overestimation of exposures was justified.

Table A5-1:Simulated Stomach Acid Leachate Test: Antimony

Level in Soil (ppm)[1]	Amount Leached (ppm)	% Leached
2.454	0.004	0.16
1.818	0.0035	0.19
2.096	0.0033	0.16
2.334	0.0033	0.14
2.826	0.0036	0.13
2.524	0.003	0.12
2.2111	0.0033	0.15
2.011	0.0026	0.13
2.416	0.0025	0.10
2.052	0.0023	0.11
Averaged Values		
2.2772	0.00314	0.14
Minimum % Leached		0.10
Maximum % Leached		0.19

1: ppm is equivalent to μg/g in soil and μg/ml in leachate

Table A5-2:Simulated Stomach Acid Leachate Test: Arsenic

Level in Soil (ppm)[1]	Amount Leached (ppm)	% Leached
52.0	0.704	1.35
39.1	0.556	1.42
45.0	0.576	1.28
50.2	0.689	1.37
63.1	0.396	0.628
44.8	0.386	0.860
43.1	0.430	0.998
42.2	0.526	1.24
62.3	0.544	0.872
37.6	0.514	1.36
Averaged Values		
48.0	0.532	1.14
Minimum % Leached		0.623
Maximum % Leached		1.42

1: ppm is equivalent to μg/g in soil and μg/ml in leachate

Table A5-3:Simulated Stomach Acid Leachate Test: Beryllium

Level in Soil (ppm)[1]	Amount Leached (ppm)	% Leached
	Below Detection Limits	
Averaged Values		
Minimum % Leached		
Maximum % Leached		0.19[2]

1: ppm is equivalent to $\mu g/g$ in soil and $\mu g/ml$ in leachate
2: substitute value, see text

Table A5-4:Simulated Stomach Acid Leachate Test: Cadmium

Level in Soil (ppm)[1]	Amount Leached (ppm)	% Leached
	Below Detection Limits	
Averaged Values		
Minimum % Leached		
Maximum % Leached		0.19[2]

1: ppm is equivalent to $\mu g/g$ in soil and $\mu g/ml$ in leachate
2: substitute value, see text

Beryllium and cadmium levels in leachate were below detection limits. Therefore the lowest soil leaching value (0.19%) reported for antimony was used to provide estimates of the amount of beryllium and cadmium leached for soil by stomach acid. This approach will provide conservative estimates of the amount of beryllium and cadmium that are bio-accessible.

Table A5-5:Simulated Stomach Acid Leachate Test: Cobalt

Level in Soil (ppm)[1]	Amount Leached (ppm)	% Leached
200	1.96	0.98
180	1.66	0.92
130	1.17	0.90
140	1.23	0.88
210	2.35	1.1
160	1.71	1.1
220	1.69	0.77
150	1.85	1.2
230	1.44	0.63
120	1.29	1.1
Averaged Values		
174	1.64	0.96
Minimum % Leached		0.63
Maximum % Leached		1.2

1: ppm is equivalent to $\mu g/g$ in soil and $\mu g/ml$ in leachate

Table A5-6:Simulated Stomach Acid Leachate Test: Copper

Level in Soil (ppm)[1]	Amount Leached (ppm)	% Leached
990	17.2	1.7
770	17.1	2.2
1000	19.1	1.9
780	14.2	1.8
1000	15.9	1.6
840	14.7	1.8
1000	20.5	2.1
980	20.7	2.1
970	16.1	1.7
640	14.0	2.2
Averaged Values		
897	16.9	1.9
Minimum % Leached		1.6
Maximum % Leached		2.2

1: ppm is equivalent to µg/g in soil and µg/ml in leachate

Table A5-7:Simulated Stomach Acid Leachate Test: Lead

Level in Soil (ppm)[1]	Amount Leached (ppm)	% Leached
400	15.6	3.9
480	21.1	4.4
350	12.8	3.7
310	11.1	3.6
400	13.3	3.3
370	14.4	3.9
300	9.17	3.1
350	11.4	3.3
360	15.4	4.3
290	13.1	4.5
Averaged Values		
361	13.7	3.8
Minimum % Leached		3.1
Maximum % Leached		4.5

1: ppm is equivalent to µg/g in soil and µg/ml in leachate

Table A5-8:Simulated Stomach Acid Leachate Test: Nickel

Level in Soil (ppm)[1]	Amount Leached (ppm)	% Leached
8800	86.2	0.98
9200	107	1.16
11000	93	0.85
11000	87.9	0.8
12000	88.5	0.74
13000	96.9	0.75
14000	127	0.91
14000	115	0.82
16000	104	0.65
17000	99.9	0.59
Average		
12600	100.54	0.82
Minimum % Leached		0.59
Maximum % Leached		1.16

1: ppm is equivalent to µg/g in soil and µg/ml in leachate

APPENDIX 6

Estimating Backyard Vegetable Consumption for the Rodney Street Community

Estimating Backyard Garden Vegetable Consumption for Rodney Street

The assessment of potential health risks for people living in the homes on Rodney Street, Port Colborne considers exposures to the metals of concern from all relevant pathways. Eating vegetables grown in backyards where metal levels are above typical levels, represents a potential exposure pathway if the metals present in the soil are taken up into the vegetables. The exposures received by people eating such produce depends upon the concentration of the metals in the vegetables and the amount of vegetables consumed from backyard gardens on an annual basis. Specific data on backyard garden vegetable consumption patterns for the homes on Rodney Street are not available. Therefore it was necessary to estimate likely consumption rates based on studies conducted in other communities in Ontario (MOE, 1995). As part of the on-going work in Port Colborne, samples of backyard produce have been collected by the MOE and Jacques Whitford Environmental Limited (JWEL) from Rodney and Mitchell Streets. The levels of individual metals in the various types of produce tested are provided in Appendix 1 of this report.

The amounts and types of produce that people might consume from a backyard garden are affected by the size of the garden, the preferences of individuals for the types of crops grown and the yields achieved. In previous risk assessments in other communities, the MOE developed an estimate of backyard garden crop yield of 1.4 kg/m^2 for mixed produce (MOE, 1995). An assumed garden size of 30 m^2 was used to provide an estimated total annual yield of 42 kg of produce. These assumptions have been used to estimate backyard garden produce consumption for people living on Rodney Street.

Estimates of the daily vegetable consumption, based on Nutrition Canada surveys of the Canadian population (O'Connor, 1997) have been used to estimate the total daily and annual levels of vegetable consumption for people living on Rodney Street. Backyard fruit production does not appear to be significant at Rodney Street homes. Further, the collection of produce from these homes did not include fruit. Although data was collected from tomatoes and green peppers, these are generally considered to be vegetables and were considered as such by the Nutrition Canada survey studies. Further, fruit consumption surveys in the Canadian population include many items, such as citrus fruit and bananas that would not grow in Port Colborne. Therefore, it was believed that using a fruit category would not be representative of backyard garden produce consumption for the homes on Rodney Street. Daily consumption rates of root and other vegetables for all age groups are shown in Table A6-1.

In assessing exposures from the consumption of backyard garden produce, it has been assumed that backyard garden vegetables constitute a portion of the daily intake of vegetables every day of the year. In determining the contribution that the consumption of backyard garden vegetables makes to the annual total, it has been necessary to estimate the total annual consumption of vegetables in a typical household on Rodney Street. This assessment has assumed that a typical family consists of two adults and two children. The children were further assumed to be between 5 and 11 years of age. Based on these assumptions the total annual intake of vegetables and the contribution from backyard garden produce can be calculated as shown in Table A6-2.

To estimate daily consumption rates for backyard garden vegetables, the vegetable consumption rates listed in Table A6-1 are adjusted by the fraction that is attributable to backyard gardens. Estimates of daily backyard garden vegetable consumption are shown in Table A6-3. These values have been used to estimate metal intakes from backyard produce for the people living on Rodney Street.

Table A6-1: Daily Vegetable Consumption Rates for the Canadian Population[1]

	Vegetable Consumption Rates (g/day)				
	Infant (0 - 6 mo.)	Toddler (7 mo-4 yr)	Child (5 - 11 yr.)	Teen (12 - 19 yr)	Adult (20+ yr.)
Root Vegetables	83	105	161	227	188
Other Vegetables	72	67	98	120	137
Total Daily Consumption	155	172	259	347	325
Root as a % of Total Daily Consumption	54%	61%	62%	65%	58%
Other as a % of Total Daily Consumption	46%	39%	38%	35%	42%

1. from O'Connor, 1997.

Table A6-2: Estimation of Backyard Vegetable Contribution to Total Vegetable Consumption

Receptor	Daily Consumption (g/day)	Number	Total Daily Consumption (g/day)	Days/year	Total Annual Consumption	
					g/year	kg/year
Adult	325	2	650	365	237,250	237
Child	259	2	518	365	189,070	189
Annual Family Consumption of Vegetables					426,320	426
Annual Vegetable Yield from Backyard Garden[1]					42,000	42
% of Annual Vegetable Consumption that comes from Backyard Gardens					9.85%	9.85%

1. from MOE, 1995.

Table A6-3: Estimated Daily Consumption of Backyard Garden Produce for all Age Groups

	Vegetable Consumption Rates (g/day)				
	Infant (0 - 6 mo.)	Toddler (7 mo-4 yr)	Child (5 - 11 yr.)	Teen (12 - 19 yr)	Adult (20+ yr.)
Total Daily Consumption of Root Vegetables	83	105	161	227	188
Total Daily Consumption of Other Vegetables	72	67	98	120	137
% Consumed as Backyard Garden Produce	9.9%	9.9%	9.9%	9.9%	9.9%
Daily Consumption of Backyard Root Vegetables	8.18	10.34	15.86	22.36	18.52
Daily Consumption of Other Backyard Vegetables	7.09	6.60	9.65	11.82	13.49

A6 References:

Jacques Whitford Environmental Limited (JWEL). 2000. Document in preparation.

MOE. 1995. Health risk assessment of mercury contamination in the vicinity of ICI Forest Products Cornwall, Ontario. Ontario Ministry of Environment and Energy. May 1995. PIBS 3352.

O'Connor. 1997. Compendium of Canadian Human Exposure Factors for Risk Assessment. O'Connor Associates Environmental Inc. and G.M. Richardson. Ottawa, Ontario, Canada.

APPENDIX 7

Dermal Uptake Coefficients for Metals

Dermal Uptake Coefficients for Metals

Daily contact with metals through soil present on the skin represents a potential route of exposure. However, the insoluble nature of most metals in soil limits their bio-accessability for uptake into and through the skin. Where data is available, it shows that dermal uptake of metals is low (Paustenbach, 2000). The rate at which a metal is taken up into the outer layers of the skin is referred to as the *dermal uptake coefficient* (DUC). Studies of the dermal absorption of nickel have suggested that the outer layer of the skin, the stratum corneum, can act as a collector for dermally applied nickel before it enters the underlying tissue (Fullerton *et al.*, 1992). While there is little information on dermal uptake of the other metals of concern in this assessment, it is reasonable to assume that similar mechanisms will govern their absorption into the body. This process can be considered to be equivalent to ingestion or inhalation *intakes* where the material is delivered into the gut or lungs, but cannot be considered to have entered the body proper until it is absorbed through the gut or lung lining and into the underlying tissue or blood. Therefore, for the purposes of this assessment, dermal uptake coefficients will be used to estimate the amount of each metal that could be delivered to the skin through contact with soil (referred to as *Dermal Intake*) The calculation of dermal intakes for each metal is provided in Appendix 3.

Metal-specific dermal uptake coefficients have been identified for two of the six metals (cobalt and nickel) considered in the detailed exposure assessment. Dermal uptake coefficients for the remaining four metals (antimony, beryllium, cadmium and copper) have been derived from stomach acid leach test results (Appendix 5). The selection of the dermal uptake coefficient for each metal is discussed below.

A7-1 Dermal Uptake Coefficient for Nickel

There are several studies that address the uptake of nickel through the skin available in the literature (Norgaard, 1955, Fullerton *et al*, 1986, and Fullerton *et al.* 1992). In addition, reviews are available (ATSDR, 1997, Hostynek *et al.*, 1993). The available studies on nickel uptake in human skin have focused primarily on the uptake of nickel and its relationship with nickel contact dermatitis (Norgaard, 1955, Fullerton *et al*, 1986, and Fullerton *et al.* 1992). These studies have examined the uptake of soluble forms in nickel into the outer layers of the skin. Two types of study protocols were used to measure dermal uptake; studies where nickel compounds were applied to skin and secured with some form of patch, occluding the skin and studies where the applied material were not secured with a patch. Norgaard reported dermal uptake rates that ranged between 55 % and 77% over a 24 hour period when nickel sulphate was applied to occluded skin (Norgaard, 1955). However, it could not be determined if the nickel in this study was actually bound in the outer layers of the skin (ATSDR, 1997). This limits the utility of the study for assessing dermal absorption of nickel compounds. In a study that applied nickel chloride to excised human skin, Fullerton *et al* reported that 0.23% of the applied dose was absorbed over a 144 hour period in unoccluded skin while 3.5 % was absorbed by occluded skin (Fullerton *et al*, 1986). In a follow-up study designed to determine the efficacy of different vehicle carriers for dermal patch testing, Fullerton *et al.*(1992) reported that dermal uptake of nickel sulphate in excised human skin, ranged between 3% and 5% of the applied

dose in occluded skin over a 93 hour testing period. The study further showed that the level of absorption was dependent on the carrier vehicle used, and that the dermal absorption of dissolved nickel was greater than that of undissolved or crystalline nickel (Fullerton *et al.*, 1992). Analysis of nickel levels in the stratum corneum, epidermal and dermal layers of skin also showed that the outer stratum corneum layer held the highest levels of nickel. The study also found that little nickel was able to penetrate through all layers of the skin to the underlying tissue (Fullerton *et al.*, 1992). The authors suggest that this layer of the skin may act as a reservoir for nickel that could allow nickel to move into other tissue and that as the level of nickel increases in this layer, subsequent exposures would allow greater amounts of nickel to move through the skin (Fullerton *et al.*, 1992).

It should be stressed that the work of Fullerton *et al*, in 1992 was conducted with occluded skin. This is not representative of dermal contact with soil where exposures would not be expected to last for more than 24 hours. Further, Hostynek *et al.* note that occlusion increases skin penetration ten-fold over unoccluded conditions. The authors further note that sweat contains significantly higher levels of nickel than normal blood serum and that it is a significant excretory pathway for the metal (Hostynek *et al.* 1993). Thus, it would appear that dermal absorption of nickel from soil is likely to be very limited and that much of what is absorbed into the outer layers of the skin is likely to be lost from the skin due either to removal in sweat or through the normal loss of outer skin cells from the stratum corneum.

The study using unoccluded skin most closely resembles the dermal exposures to nickel in soil that could be expected in the Rodney Street community. Therefore, the absorption factor of 0.23%, reported by Fullerton, *et al, 1986* was used to develop a dermal uptake coefficient for nickel in Port Colborne.

As noted above, Fullerton *et al* , 1986 reported that 0.23% (0.0023) of an applied dose of nickel chloride was absorbed over a period of 144 hours. However, bathing activities can be expected to limit skin contact with nickel bearing soil to a maximum of 24 hours. Therefore, it is necessary to correct the uptake coefficient reported by Fullerton *et al,* 1986, to account for the difference in the expected exposure duration of 24 hours and the 144 hours used in the Fullerton study. In developing a corrected dermal uptake coefficient for nickel oxide, it has been assumed that soil would remain in contact with the skin for a period of 24 hours before being removed by bathing activities. The derivation of dermal uptake coefficient for nickel is shown in equation A7-1.

Eq A7-1:

$$DUC_{Ni} = 0.0023 * \left(\frac{24 hours}{144 hours} \right) = 0.00038 = 3.8X10^{-4}$$

Where:	DUC_{Ni}	=	Dermal Uptake Coefficient for nickel
	24 hours	=	Expected exposure duration
	144 hours	=	Duration of experimental exposure
	0.0023 =		Reported dermal absorption of Nickel Chloride

It should be noted that this approach assumes a linear relationship between the length of exposure and the amount of nickel available to the skin for absorption. It should also be noted that there is a marked difference in water solubilities between the nickel chloride used by Fullerton *et al,* 1986 and nickel oxide which is the predominant form of nickel found in the soil on Rodney Street and elsewhere in Port Colborne. Reported solubilities are 642 g/L and 0.0011 g/L for nickel chloride and nickel oxide respectively (ATSDR, 1997). Further, the nickel chloride used by Fullerton *et al,* was applied in solution and was freely available for absorption by the skin. In Port Colborne, the nickel oxide is associated with soil particles and must dissociated (dissolve) from the soil particles before it is available for absorption by the skin. Therefore, using a dermal dose factor derived for dissolved nickel chloride to estimate the dermal dose of undissolved nickel oxide, will significantly over estimate the amount of nickel oxide available for absorption by the skin. Thus, the *DUC* factor selected for use at Rodney Street in Port Colborne will provide conservative estimates of dermal exposure for all age groups considered in the assessment.

A7-2 Dermal Uptake Coefficient for Cobalt

Paustenbach cites a dermal uptake coefficient of 0.0004 for cobalt chloride (Paustenbach, 2000). Information on the cobalt species present in Rodney Street soil is not available. Therefore, it has been assumed that the dermal uptake coefficient for cobalt chloride is representative of the dermal uptake coefficient for cobalt in soil in the Rodney Street area.

A7-3 Dermal Uptake Coefficients for Antimony, Beryllium, Cadmium and Copper

Dermal uptake coefficients for the remaining metals are not available. In the absence of such values, a default value of 0.01 is recommended by the US EPA for assessing dermal exposure to inorganic compounds such as metals (US EPA, 1992). However, this recommendation is based on the conservative assumption that all metal delivered to the skin is available for uptake into the skin. The metals in Port Colborne soils appear to be tightly bound to the soil matrix and therefore would not be fully available for uptake through the skin. As noted in elsewhere in this report, the amount of each metal that could be released for the soils from Rodney Street, under acidic conditions has been assessed (Appendix 5). The maximum levels of metals released under these conditions ranged between 0.19% (0.0019) for antimony to 2.2 % (0.02) for copper. These values represent the maximum amount of each metal that could be expected to be released from the soil while in contact with skin. Therefore, these values have been used as the dermal uptake coefficients for estimating dermal exposure to these metals. By assuming that the amount of metal released under acidic conditions will be equivalent to the amount of metal released under neutral pH conditions will over estimate the amount of metal released and subsequent exposures. The dermal uptake coefficients used in this report are summarized in Table A7-1.

Table A7-1: Dermal Uptake Coefficients

	Antimony	Beryllium	Cadmium	Cobalt	Copper	Nickel
Coefficient	0.0019	0.0019	0.0019	0.0004	0.022	0.00038

A7 References:

ASTDR (Agency for Toxic Substances and Disease Registry), 1997. U.S. Department of Health and Human Services. Toxicological Profile for Nickel. Atlanta, Georgia, USA.

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Hostynek, J.J., R.S. Hinz, C.R. Lorence, M. Price, and R.H. Guy. 1993. Metals and the skin. CRC Critical Reviews in Toxicology 23: 171-235.

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